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MINIREVIEWS

Hamstring autograft utilization in reconstructing anterior cruciate ligament: Review of harvesting techniques, graft preparation, and different fixation methods

Waleed Albishi, Baraa Baltow, Nora Albusayes, Ameer A Sayed, Hamza M Alrabai

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Waleed Albishi, Nora Albusayes, Hamza M Alrabai, Department of Orthopedic Surgery, College of Medicine, King Saud University, Riyadh 11362, Saudi Arabia

Baraa Baltow, Department of Orthopedic Surgery, AlHada Armed Forces Hospital, Ministry of Defense, AlHada 26792, Saudi Arabia

Ameer A Sayed, Department of Orthopedic Surgery, King Fahad Armed Forces Hospital, Ministry of Defense, Jeddah 23311, Saudi Arabia

Corresponding author: Nora Albusayes, MBBS, Doctor, Staff Physician, Department of Orthopedic Surgery, College of Medicine, King Saud University, 7804 Street No. 18, Riyadh 11362, Saudi Arabia. nalbusayes@gmail.com

Abstract

Rupture of the anterior cruciate ligament (ACL) is a common orthopedic injury. Various graft options are available for the reconstruction of ruptured ACL. Using the hamstring muscle as an autograft was first described in 1934, and it remains a commonly harvested graft for ACL reconstruction. Hamstring autografts can be harvested using the traditional anteromedial approach or the newer postero-medial technique. An isolated semitendinosus tendon can be used or combined with the gracilis tendon. There are numerous methods for graft fixation, such as intra-tunnel or extra-tunnel fixation. This comprehensive review discusses the different hamstring muscle harvesting techniques and graft preparation options and fixation methods. It provides a comprehensive overview for choosing the optimal surgical technique when treating patients.

Key Words: Anterior cruciate ligament; Anterior cruciate ligament reconstruction; Graft fixation; Hamstring autograft; Infrapatellar nerve injury; Patient reported outcomes

Core tip: Anterior cruciate ligament (ACL) rupture is a common orthopedic injury and various graft options are available for the reconstruction of a ruptured ACL. This comprehensive review discusses the different hamstring muscle harvesting techniques as well as graft preparation and fixation methods that can be used to guide clinicians in making evidence-based decisions when treating their patients.

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INTRODUCTION

The knee is a weight-bearing joint that gains stability through various supportive structures[1]. Limiting tibial translation, cruciate ligaments act as the greatest stabilizing force of the knee[2]. The anterior cruciate ligament (ACL) extends from the posteromedial aspect of the femoral lateral condyle to the tibial eminence in the anteromedial and posterolateral bundles. It functions by preventing anterior displacement of the tibia in the sagittal plane[1,2]. A common orthopedic complaint is the ACL injury. Sanders *et al*[3] reported in his 21-year population-based study that the annual incidence of ACL injury is 68.6 per 100 000 person-years.

The ACL can be injured by either a direct contact force to the knee or a noncontact mechanism by landing or deceleration motion which represents 70% of ACL cases[4]. Boden *et al*[5] described the event as a combination of the misdirected kinetic energies that results in the “twisting event” of a valgus knee and tibial internal rotation in addition to the columnar buckling effect.

Patients usually describe an ACL injury with an audible loud pop followed by an immediately swollen painful knee. Later, incidents of giving way to pivot movements may also occur[6,7]. Examination of the affected extremity is an effective diagnostic tool, whereas magnetic resonance imaging is the main diagnostic confirmatory tool. Although multiple factors influence the management of a patient with a ruptured ACL, limited data support the choice of a purely conservative management[6,8]. Various graft options are available for the reconstruction of a ruptured ACL. The two main graft categories are allografts [bone-patellar tendon-bone (BTB), hamstring, tibialis anterior and posterior, peroneal, Achilles] and autografts (BTB, quadriceps, and hamstring)[9]. The semitendinosus (ST) tendon, which is the hamstring tendon used for ACL rupture (ACLR), is found on the medial side of the knee between layer I (encompassing the sartorius muscle) and layer II (encompassing the superficial medial collateral ligament) as described by Warren *et al*[10] and Nichalas *et al*[11]. The insertion of the ST tendon is on the anteromedial aspect of the tibia on the conjoining structure of the pes anserinus together with the gracilis and sartorius tendons[12,13]. In general, better outcomes found in the literature support the use of autografts than allografts. Moreover, hamstring tendon autograft is one of the optimal choices for reconstructing a ruptured ACL. This is because of the lower failure rates in comparison to that of allografts and avoidance of anterior knee pain found with BTB grafts[9]. In 1934, Galliazi was the first orthopedic surgeon to describe the use of the hamstring tendon as an autograft for ACLR[14]. The aim of this review is to discuss the different hamstring muscle harvesting techniques, graft preparation options, and fixation methods.

The reference numbers will be superscripted in square brackets at the end of the sentence with the citation content or after the cited author’s name, with no spaces.

METHOD/LITERATURE SEARCH

We searched for the following keywords in the PubMed database: hamstring autograft, hamstring harvest, infrapatellar branch of the saphenous nerve (IPBSN) injury, saphenous nerve injury, posteromedial hamstring harvest, semitendinosus autograft, gracilis tendon autograft, ACL fixation, and suspensory interference screws. The main review question was “What are the strategies of hamstring autografts available for ACL reconstruction?” and “How are they harvested, prepared, and fixated?” The article collection was not limited to PubMed search of the previously mentioned terms, and further studies were identified and retrieved through citations. Articles were assessed for relevance for inclusion in this review based on the titles and abstracts. The database was searched up to August 22, 2021. Non-English papers and case reports were excluded.

GRAFT HARVESTING

Anteromedial technique

Typically, the hamstring tendon is harvested using the anteromedial approach. The incision is performed medial to the anterior tibial tuberosity and 4–6 cm distal to the joint line. The direction and length of the incision differed based on the surgeon's preference. This is followed by dissection of the subcutaneous tissue until the sartorial tendon in layer I is exposed. Beneath this layer, the semitendinosus and gracilis tendons are found. Once the tendons are identified, harvesting can be performed in two ways: (1) Dissecting the tendons distally, stripping proximally with a closed stripper; and (2) using an open stripper proximally and then stripping distally with a closed stripper. In the first technique, a whip stitch is used for countertraction during harvest. Second, a right-angled retractor is used for countertraction while stripping the tendon[12,13,15,16].

Hamstring tendon harvest may be associated with complications including injury to the medial collateral ligament, premature amputation of the tendon, and injury to the infrapatellar saphenous nerve[12,13,17]. Several methods have been proposed to overcome these complications.

In dissecting through the sartorius tendon in layer I to reach the ST and GT, extreme caution and adequate anatomical knowledge are advocated to avoid injuring the superficial medial collateral ligament immediately below the two tendons in layer II[12,13]. In the new OLIBAS harvesting technique recently published, Olivos-Meza *et al*[17] proposed the use of the tibial tubercle and medial border of the tibia as landmarks for an easier harvest with fewer complications. MCL injury is suggested to be reduced by a couple of maneuvers in the dissection technique. First, the superficial dissection of the subcutaneous tissue using a No. 15 blade with a vertical incision line, followed by blunt dissection medially and laterally with retractors, and further cleaning of any remnants with 360° motion using wet gauze. Second, direct, safe access to the tendons between the sartorius tendon and MCL by blunt introduction of Kelly forceps into the over-elevation landmark representing the gracilis as seen through the incision while the knee is in 90º flexion. The semitendinosus tendon contains multiple accessory bands. Meticulous dissection of such bands is crucial to prevent harvesting of a graft shorter than expected. Before advancement of the stripper, scissors can be used to release bands while the tendon is taut forcefully by a Penrose drain if the surgeon has chosen a proximal to distal grafting direction or by the whip stitch if a distal to proximal direction is preferred[12,13]. Olivos-Meza *et al*[17] urged manual exploration of expansions by introducing the index finger along the tendon path and rotating it 360º. Any expansions felt should be exposed through the incision by a Kelly and cut. Colombet *et al*[18] described another approach in identifying all expansions. By pulling out expansions through the incision one by one using an alternative probe hook maneuver, more expansions are exposed. The stripper could be easily advanced 10 cm without resistance, indicating that no expansions were left. The direction of the stripper is proposed to reduce the risk of premature amputation when it is aimed at the origin of the ST, ischial tuberosity, or lesser trochanter when harvesting the GT[13]. Another issue that might require a surgeon to use another graft is retraction and loss of tendons during stripping. This complication is thought to be reduced in the OLIBAS technique by holding the tip of the tendon perpendicularly with strong forceps and rolling it multiple times until the knuckles of the surgeon's nondominant hand rest on the operated knee while advancing the stripper firmly and gently with the dominant hand[17].

The saphenous nerve gives rise to two branches as it exits the adductor canal: the infrapatellar and sartorial branches[19]. The IPBSN is a small cutaneous nerve supplying the anterior aspect of the knee, anterolateral aspect of the leg, and anteroinferior aspect of the knee joint capsule[20]. The sartorial branch provides sensory innervation to the medial aspect of the leg and ankle[19].

Injury to the IPBSN is a common complication of the anteromedial approach for ACL reconstruction. The reported prevalence of IPBSN injury using the anteromedial approach ranges from 21.1% to 83%[15,19-29]. This injury can cause hypoesthesia, dysesthesia, painful neuroma, and reflex sympathetic dystrophy[28]. Pagnani *et al*[12] and Solman *et al*[13] implemented a figure of four position with the knee flexed and the hip abducted and externally rotated during harvest. This position allows the saphenous nerve located on top of the gracilis at the posteromedial joint line to relax, reducing the risk of injury. Pękala *et al*[30] also recommended the use of a figure of four position. Despite the use of this configuration, Figueroa *et al*[28] in their prospective study found 77% of patients to have clinical hypoesthesia and electrophysiological denervation of the IPBSN postoperatively using a vertical incision. They concluded that this nerve injury must have occurred during the harvest since the saphenous nerve is far from the incision and would only be at risk during stripping where a sharp instrument is near. Mahmood *et al*[21] have conducted a similar study using an oblique anteromedial incision. They found that 24% of patients complained of hypoesthesia, and the same patients were found to have IPBSN injury on electrophysiological study. Sanders *et al*[15] performed a survey-based study of patients who underwent ACL reconstruction through a vertical anteromedial incision while also utilizing the figure of four position. Among the participants, 74% reported disturbed sensation. In their anatomical analysis, Sanders *et al*[15] concluded that injury to the SBSN and IPBSN can occur during tendon stripping, especially when using a mini-incision that obligates the surgeon to blindly harvest the tendons. An anatomical study aimed at describing the IPBSN course with regard to surgery around the knee was also conducted. The IPBSN was found to have a highly variable coarse, the most common variant being the posterior pathway in 56% of the knees (arising along the inferior posterior border of the sartorius muscle), found alone in 28%, and in association with the intramuscular (piercing through the sartorius muscle) and/or the anterior pathway (anterior border of the sartorius muscle) in 28%. Walshaw *et al*[31] also concluded that the IPBSN is mostly damaged during tendon harvesting with the stripper owing to its close proximity to the ST and GT.

The lower prevalence of injury observed in the study by Mahmood *et al*[21] in comparison to Figueroa *et al*[28] and Sanders *et al*[15] can be attributed to the orientation of the incision. This may be attributed to the subcutaneous oblique course of the infrapatellar nerve inferior to the patella that occupies the anteromedial region of the knee with its multiple branches, as reported by Hunter *et al*[32]. Two meta-analyses found that the risk of IPBSN injury during ACL reconstruction was significantly higher with vertical incisions than with oblique incisions[30,33]. Pękala *et al*[34], by simulating differently directed incisions in an ultrasound study on healthy knees, have also documented a similar risk reduction for oblique incision over the vertical incision. Multiple randomized controlled trials have studied the effect of incision direction on this complication. Keyhani *et al*[25], Mousavi *et al*[27], Sabat *et al*[22], Joshi *et al*[23], and Luo *et al*[19] found a decreased risk of IPBSN injury using the oblique incision compared to that with a vertical traditional incision (Table 1).

In contrast, Chen *et al*[29] and Leiter *et al*[35] found no relationship between the incision direction and IPBSN injury. The larger incision length in these two studies may be the reason, as Luo *et al*[19] found that the average distance between the upper edge of the pes anserinus and IPBSN was 0.6 cm. Mahmood *et al*[21] found a significant association between incision length and risk of IPBSN injury. Moreover, the use of a shorter incision was strongly supported in the meta-analysis by Pękala *et al*[30] and Henry *et al*[20] in an anatomical study where they measured the safe distance between an incision and a nerve to be 0.82–0.87 cm (Table 1).

Shorter incisions with adequate access to the hamstring tendons have been proposed. In 2016, Colombet *et al*[18] suggested the use of a small 2-cm vertical incision over the palpable pes anserinus. This incision is intended to decrease the incidence of IPBSN injury and is the cosmetically preferred option. Direct access to the tendons can be achieved by a 3-cm horizontal incision over the fascia following careful soft tissue dissection using Metzenbaum scissors. In the OLIBAS technique, the unique anatomical landmark used for incision placement also plays a role in the use of a smaller vertical/oblique incision (1.5 cm), which allows for cosmetic benefit with direct access to the tendons. The incision is located on a horizontal line drawn between the two landmarks (tibial tubercle and medial border of the tibia) and divided into thirds, and a vertical or oblique incision is made in the second third. The risk of nerve injury is reduced during subcutaneous tissue dissection, as sharp dissection is only performed in a proximal–distal direction, while further medial–lateral dissection is performed bluntly with two Farabeuf retractors[17]. A unique inverted L-shaped incision of the sartorial fascia has been used by multiple surgeons to allow direct access to the hamstring tendons and reduce the risk of nerve injury[15,17,23]. In a cadaveric study, Tillett *et al*[36] proposed a uniquely placed incision, which is claimed to be located in a safe zone where neurological injury is prevented and direct access to tendons is achieved. This incision is inclined approximately 30º from the vertical, starting at a point 3 cm medial to the apex of the tibial tuberosity and ending 5 cm medial to it. The authors used this incision in 45 patients with no complications.

Ultrasound can readily visualize the IPBSN and its main trunks over the pes anserinus, which are at risk during skin incision. Therefore, preoperative identification of the anatomical distribution of the IPBSN by ultrasound is recommended to reduce the incidence of iatrogenic nerve injury by finding a safe area for the incision. However, smaller branches were not detected[30,34]. Regardless of the orientation of the incision, IPBSN iatrogenic injury remains an unavoidable complication of hamstring tendon harvesting using an anteromedial approach. The previous statement was supported by Leiter *et al*[35] since a safe zone to prevent IPBSN injury could not be found and nerve distribution was highly variable regarding the number and orientation of branches. Accordingly, an incision that is as small as possible and preferably oblique should always be the goal to limit the number of possibly injured branches[30,34,35]. Furthermore, multiple studies have demonstrated smaller areas of hypoesthesia in patients with oblique incisions than in those with vertical incision[19,22,35] (Table 1).

Posteromedial technique

To avoid some of the aforementioned complications, Franz *et al*[37] pioneered a new approach in harvesting the hamstring tendon from the popliteal fossa. Franz's technique starts with the leg in a figure of four position, with the knee in 60º flexion, allowing for relaxation and protection of the saphenous nerve. The incision is made horizontally on the popliteal crease on top of the semitendinosus tendon, which is palpable in the posteromedial aspect of the popliteal fossa. A visible anatomical landmark to help locate the incision is the Jobert's groove, which is described by Prenkopf, representing the space between the adductor muscle group from the ST. Vertical dissection of the fascia follows. A FiberTape suture is looped around the tendon. The tendon is pulled out through the incision while the knee is flexed to 90º, permitting visualization and dissection of the distal accessory insertions, and avoiding premature graft amputation. Distal-to-proximal harvesting is carried out with an open stripper first to release proximally. Afterwards, a closed tendon stripper is advanced to release the tendon from its insertion distally while palpating the stripper on the anteromedial aspect of the tibia with caution not

Table 1 Incision direction/length, neurological injury, area of hypoesthesia

Ref.	Direction/length of incision	Prevalence of IPBSN injury	Area of hypoesthesia
Keyhani *et al*[23], 2019	Vertical: 3.8 cm; Oblique: 2.7 cm	IPBSN 40%; Vertical 56.8%; Oblique 25%	Vertical 34.2 cm^2; Oblique 9.6 cm^2
Mousavi *et al*[25], 2018	Vertical: 5.1 cm; Oblique: 3.8 cm	IPBSN 83%; Vertical 95.8%; Oblique 61.3%	Vertical 59.9 cm^2; Oblique 11.5 cm^2
Sabat *et al*[29], 2012	Vertical: 4.1 cm; Oblique 3.8 cm	[1]IPBSN 48%; [1]Vertical 76%; [1]Oblique 32%	[1]Vertical: 44.6 cm^2; [1]Oblique: 14.4 cm^2
Joshi *et al*[23], 2016	Vertical: 3 cm; Oblique: 3 cm	IPBSN 21.1%; Vertical 25%; Oblique 16.36%	N/M
Luo *et al*[19], 2007	Vertical 3.4 cm; Oblique: 3.3 cm	IPBSN 48%; Vertical 65.7%; Oblique 24%	Vertical: 48 cm^2; Oblique: 8.4 cm^2
Sharaby *et al*[29], 2019	Vertical 5 cm; Oblique: 5.2 cm	IPBSN: 69.2%; Vertical: 39.5%; Oblique: 24%	N/M
Mahmood *et al*[21], 2020	Oblique: 2.9 cm	IPBSN: 24%	Oblique: 3.9 cm^2
Figueroa *et al*[28], 2008	Vertical: 1.8 cm	IPBSN: 77%	Vertical: 3.6 cm^2
Sanders *et al*[15], 2007	Vertical: 1.5-2 cm	IPBSN: 19%	N/M
Ochiai *et al*[24], 2017	Vertical: 1.8-2.5 cm	21.1%	N/M

[1]Six months postoperatively.

IPBSN: Infrapatellar branch of the saphenous nerve (total prevalence of hypoesthesia over the infrapatellar branch of the saphenous nerve distribution measured clinically); N/M: No mention.

to perforate the skin. The same incision can be used to harvest the gracilis if the surgeon chooses to follow the same procedure[37].

Kodkani *et al*[38] implemented a posteromedial technique with some modifications. A small incision (1–1.5 cm) was made horizontally at the same location as described by Franz. To grant better access to the tendons, the knee was flexed at 30º and externally rotated. Knee flexion was increased for optimal identification and cutting of distal fibrous bands. After freeing the tendon proximally, the distal insertion was released while the knee was completely flexed and internally rotated. In a review of eight cases, Kodkani *et al*[38] reported zero intraoperative and postoperative complications, and all patients had satisfactory cosmetic results. Letartre *et al*[39] further modified this technique. During the procedure, the surgeon conveniently faced the posterior aspect of the knee. This view was achieved while the hip was flexed, and the knee flexed at 20º. An assistant held the limb up by the foot and applied external rotation. A 3–4-cm horizontal incision over the palpable ST was then made. Proximally, the tendon was harvested at 120º flexion. Distal harvesting was performed using a closed, short stripper. In an evaluation of 90 patients prospectively, a complete failure of harvest was reported during their first attempt for the posteromedial approach that required conversion to the anterior approach. In another case, the gracilis was harvested mistakenly instead of the semitendinosus, while in two cases, the ST alone resulted in a weak graft that was reinforced by the gracilis. In addition, no premature ambulation of the graft or sensory deficit occurred in any of the patients.

Wilson *et al*[40] described a vertical posteromedial incision. This incision was made while the leg was in a figure of four position, starting from the popliteal crease where the ST was palpable and extended 2–3 cm proximally. The longitudinal orientation of the incision was thought to improve wound healing, prevent wound complications, and provide a cosmetically appealing option. The tendon was extracted from the wound, and fibrous extensions were dissected until no calf pinching was visible, which indicated missed bands. Proximal to distal stripping was then performed.

A double incision technique using both an anterior and a posterior incision was described by Prodromos *et al*[41] with a posterior 2-cm incision while the knee was in 30º flexion in a figure of four position. The incision could be performed vertically or horizontally using the ST as a starting point. Both the ST and GR were pulled out through the wound and held by Penrose drains. The anterior 2-cm incision was made at the ST insertion, as guided by the surgeon's index finger, following the course of the tendon from the posterior, and tenting the skin which marks the location. The incision was obliquely inclined at 45° in relation to the tibia and perpendicular to the pes anserinus. The tendon was harvested proximally with an open stripper from the anterior incision and passed through the posterior incision. At this point, the tendon could be delivered through an anterior incision, and distal release was initiated by cutting the periosteum along the superior and inferior edges of the pes anserinus with a scalpel. Strong pulling of the tendons resulted in periosteal elevation of 1 cm approximately along with the tendon. The attached part of the periosteum was incised sharply. This was thought to increase the length of the tendon by adding 1 cm of periosteum and approximately 2 cm of pes anserinus. Accessory tendons were cut with a no. 15 blade or Metzenbaum scissors as they obscured the advancement of the stripper. In a chart review of 175 patients who underwent this technique, no intraoperative difficulties or complications were encountered. The wounds healed without further complications except for one

Table 2 Advantages of using the posteriomedial approach to harvest hamstring tendons

Advantages of the posteriomedial hamstring harvesting approach over the anteromedial approach
Better cosmetic appearance
Lower risk of infrapatellar branch of the saphenous nerve injury
Direct visualization of the bands attached to the hamstring tendons which facilitate their release
Lower risk of premature amputation of the harvested grafts
Easier approach when harvesting of a single tendon is desired
Lower risk of medial collateral ligament injury
Smaller incision for the tibial drill guide with the advantage of placing the incision in the desired location

incidence of anterior cellulitis that was managed conservatively with antibiotics. Wound healing and cosmesis were thought to be superior in the posterior incision. In fact, 80% of patients thought they had a better scar appearance compared to that of others who underwent ACL reconstruction[41].

Khanna *et al*[42] recently described a posterior hamstring harvesting technique for pediatric and adolescent subjects. The incision was made horizontally 2–3 cm in length over the palpable ST, while the leg was abducted, and externally rotated. A proximal-to-distal harvest was adopted. The semitendinosus accessory band was excised and the gracilis was harvested in a similar manner. A total of 214 patients were followed up for a minimum of 6 mo for complication analysis. In all cases, the tendons were identified intraoperatively, and no incidence of premature graft transection was reported. No wound healing issues, painful scars, restriction of knee motion due to incision location, or neurovascular injuries were observed. The patient also reported no cosmetic concerns.

Anteromedial versus posteromedial technique

The traditional anteromedial hamstring harvest was compared with the posteromedial approach as described by Franz *et al*[37]. They conducted a randomized controlled trial (RCT) with 100 patients and found that the average ST harvest time was significantly lower in the posteromedial group. Although the harvested graft was sufficient in length for both groups, the average length was significantly longer in the anteromedial group with a 2-cm difference. Fourteen percent of patients in the anteromedial group reported sensory deficits along the distribution of the saphenous nerve, compared to zero sensory issues in the posteromedial group. Pain scores using the visual analog scale were similar in both groups. No wound complications were found in the posteromedial group, whereas one case in the anteromedial group had a superficial wound infection which was treated conservatively with oral antibiotics. Patients who underwent a posteromedial incision had a significantly smaller incision than those who underwent a vertical anteromedial incision.

Shu *et al*[43] retrospectively reviewed 29 patients who underwent a posteromedial harvest as described by Wilson *et al*[40]. Among these patients, 22 underwent an anteromedial harvest. Operative and tourniquet times were significantly lower in the posteromedial group. This could be explained by the ease of tendon and accessory band identification using the posteromedial approach. The posteromedial group also had a reduced risk of unintentionally harvesting the gracilis. Both groups had no incidence of premature tendon amputation or IPBSN injury. The patients were then contacted for subjective knee scores, including Knee Osteoarthritis and Outcomes Score, Western Ontario and McMaster Universities Osteoarthritis Index, and International Knee Documentation Committee score (IKDC). All scores showed no significant differences between the two groups.

In the posteromedial incision, tendons are readily identified, and adequate exposure of all extensions and accessory insertions can be achieved[38,40]. Specifically, the most important ST accessory insertion found in 90% of patients is attached to the medial head of gastrocnemius. This band is found 2.6 cm below the posterior incision and 7.6 cm away from the anterior approach[44]. Posterior direct access to the tendon can be achieved even in obese patients, as the tendons are palpable posteriorly and have little subcutaneous tissue coverage[37]. Roussignol *et al*[44] found that a 3-cm posterior incision was sufficient in identifying tendons and cutting accessory insertions with the complete avoidance of premature transection of the graft.

Neurological injury of the saphenous nerve and its branches is avoided in a posterior approach, as the nerve is protected from the sharp stripper by the sartorial fascia that is left intact in this technique[38, 44]. Therefore, none of the studies included in this review reported such complications following the posteromedial approach (Table 2).

In a prospective clinical study, Ochiai *et al*[24] reported a low IPBSN injury rate of 21.1% following an anteromedial approach using a vertical incision. This may be explained by the long follow up of 24 mo compared with the 77% at 3 wk post reconstruction in the study by Figueroa *et al*[28]. Luo *et al*[19], Sabat *et al*[22], Leiter *et al*[35], and Chen *et al*[29] reported that the area of sensory disturbances healed over time. Similarly, Joshi *et al*[23] reported gradual improvement in paresthesia within a year. Recovery was also noted to be faster with an oblique incision than with a vertical incision. A hypothesis generated to support the difference was that in the oblique incision, IPBSN injury results in neuropraxia, while the vertical incision results in a neurotmesis injury[23]. Sabat *et al*[22] and Mousavi *et al*[27] reported higher satisfaction rates in patients who underwent oblique incision than in those who underwent vertical incision. In contrast, Grassi *et al*[33] reported that the incision orientation had no impact on the Lysholm score or patient subjective satisfaction. Ochiai *et al*[24] reported no significant difference in Lysholm score, visual analog scale pain score, patient-based SF-36, and presence of anterior knee pain in relation to IPBSN injury. However, patients with IPBSN were found to be significantly less satisfied than patients without this complication[21]. Apart from the above-mentioned studies, Sanders *et al*[15], Keyhani *et al*[25], Figueroa *et al*[28], and Sabat *et al*[22] reported that the majority of patients with a neurological injury post-operatively thought that it had no significant effect on their daily activities.

GRAFT PREPARATION

Once the hamstring tendons are completely harvested, muscular remnants are removed. Based on the choice to harvest the semitendinosus alone or together with the gracilis, the preparation differs. For a four-strand (quadrupled) semitendinosus graft (4-ST), the ST is folded with a nonabsorbable suture in the middle, and the two ends are stitched with a nonabsorbable suture. The graft is folded again with a nonabsorbable suture in the middle, held on a suspensory device, and whipstitched from proximal to distal. In case both semitendinosus and gracilis (2ST-2GT) are harvested, a four-strand graft is created with both tendons folded and loaded on a suspensory device. A nonabsorbable suture is passed twice around the free ends, and the tendons are whipstitched with a nonabsorbable suture once from distal to proximal, and again from proximal to distal[45]. These graft options are most commonly used when hamstring autografts are preferred[46].

4ST versus 2ST-2GT hamstring autograft

To guide the choice between 4ST and 2ST-2GT autografts, multiple investigators have compared patient-reported outcomes as well as hamstring muscle strength following ACL reconstruction. Ardern *et al*[47] stated that harvesting the gracilis along with the semitendinosus resulted in a deficit in isometric strength at deep knee flexion angles. Furthermore, Sharma *et al*[46] also found a large difference between ST autograft subjects and STGT autograft subjects in isometric strength at deep flexion angles in a meta-analysis. A significant decrease in active knee flexion angle after STGT harvesting has been reported[46,47]. Similar with isometric strength, active knee flexion is evaluated while the hip is in relative extension, aiding in demonstrating hamstring muscle insufficiency. A significant difference in isokinetic peak torque was found by Chin *et al*[48]. This deficit is rarely found in the literature because the isokinetic flexion peak torque is generated at shallow angles that are produced by the contraction of the biceps femoris rather than the semitendinosus and/or gracilis. Additionally, the peak torque is measured while the hip is flexed to 90, a suboptimal position for the hamstring to flex the knee[47].

In an RCT, Tashiro *et al*[49] evaluated hamstring muscle strength and compared the results between patients who had both tendons harvested and patients with isolated ST harvest. The STGT group had significantly weaker isometric and isokinetic hamstring strength than the group with preserved gracilis. Both groups were found to have significantly weaker hamstrings at angles of 70º and deeper in isokinetic and isometric evaluations compared to the preoperative status. Similarly, Nakamura *et al*[50] found a significant hamstring strength deficit identified using isokinetic testing at 90º in both groups. However, no difference was observed between the STGT and ST groups. A significantly lower active knee flexion angle in the STGT group was found. Hu *et al*[51] reported a significantly higher strength deficit in the STGT group during isometric flexion at 90º. A trend of increasing deficit with increasing angle was also noted[49,51]. A loss in active knee flexion angle was significantly higher in the STGT group than in the ST group in a prospective review by Adachi *et al*[52]. However, no significant difference was reported in hamstring isokinetic strength evaluation[52]. Yosmaoglu *et al*[53] in another prospective review reported a significantly higher hamstring isokinetic deficit in flexion at 60º in subjects post-STGT autograft harvest than in subjects post-ST autograft harvest. Three RCTs by Carter *et al*[54], Karimi-Mobarakeh *et al*[55], and Gobbi *et al*[56]; two prospective cohort studies by Inagaki *et al* [57] and Segawa *et al*[58], and three retrospective studies by Ardern *et al*[59], Barenius *et al*[60], and Lipscomb *et al*[61] found no difference in flexion hamstring strength deficit after ACL reconstruction with an isolated ST harvest or a combined ST and GT harvest. Of the studies included in this review, only two investigated rotational muscle strength and compared patients after STGT autograft and ST autograft. Segawa *et al*[58] in their prospective review have reported a significantly higher deficit of internal rotation at 30º and 120º in the STGT group. This same strength deficit was found to be significantly more common in females than in males. Additionally, Gobbi *et al*[56] found a significantly greater deficit in isokinetic internal and external rotation at 60º.

The large number of articles with different study designs that reported no difference in hamstring strength between the two groups could be attributed to the method of strength evaluation used[47].

Table 3 Hamstring graft preparation techniques: summary of results

Graft preparation		
Ref.	**Study design**	**Results/conclusion**
Ardern *et al* [47], 2009	Systematic review	ST-GT autograft have a significantly higher deficit in isometric strength at knee flexion ≥ 70°. Significant standing knee flexion angle deficit in the ST-GT autograft group.
Sharma *et al* [46], 2015	Meta-analysis	ST-GT group had a significantly higher isokinetic hamstring strength deficit at 60°. ST-GT group had a significantly higher isometric hamstring strength deficit at 90°, 105°, 110°. ST-GT group had a significantly higher standing knee flexion angle deficit.
Chin *et al*[48], 2018	Meta-analysis	ST-GT group had a significantly increased s deficit in isokinetic peak torque when compared with ST group for flexion at 60°/s at 2-yr follow-up, and flexion at 180°/s at 1- and 2-yr follow-up.
Tashiro *et al* [49], 2003	RCT	ST-GT group had a significantly increased deficit in isokinetic peak torque measured at knee flexion 60°/s at 80°, 90°, 110° when compared with ST group at 18 mo postoperatively. ST-GT group had a significantly higher isometric hamstring strength deficit at 70° measured in sitting position at 18 mo postoperatively. ST-GT group had a significantly higher isometric hamstring strength deficit at 70° and 90° measured in prone position at 18 mo postoperatively. Both groups showed significant isometric and isokinetic strength deficit when compared to preoperative measures.
Nakamura *et al*[50], 2002	Consecutive sample, case–control study	ST-GT group had a significantly higher standing knee flexion angle deficit. Decreased isokinetic torque at 90° in both groups.
Hu *et al*[51], 2020	Retrospective comparative	ST-GT group had a significantly higher isometric hamstring strength deficit at 90° flexion. Significant difference in the KOOS pain score.
Adachi *et al* [52], 2003	Prospective review	ST-GT group had a significantly higher standing knee flexion angle deficit.
Yosmaoglu *et al*[53], 2011	Prospective review	ST-GT group had a significantly higher hamstring isokinetic flexion strength deficit at 60°/s.
Carter *et al* [54], 1999	RCT	No difference in isokinetic strength deficit between ST-GT and ST groups, measured at 180°/s and 300°/s. Majority of patients had activity limitation at 6 mo postoperatively.
Karimi-Mobarakeh *et al*[55], 2014	RCT	No difference in isometric strength deficit between ST-GT and ST groups, measured at 90° flexion, extension, adduction, or abduction. No difference in patient outcome measures between ST-GT and ST groups.
Gobbi *et al* [56], 2005	RCT	ST-GT group had a significantly higher hamstring isokinetic internal and external rotation strength deficit at 60°/s.
Inagaki *et al* [57], 2013	Prospective comparative	No difference in isokinetic strength deficit between ST-GT and ST groups, measured at 60°/s. No difference in anterior laxity, or knee ROM. No difference in patient reported outcomes.
Segawa *et al* [58], 2002	Prospective study	ST-GT group had a significantly higher hamstring isokinetic internal rotation at 120°/s and 30°/s.
Ardern *et al* [59], 2010	Retrospective comparative	No difference in isometric strength deficit between ST-GT and ST groups, at 30°, 90°, or 105°. No difference in isokinetic strength deficit between ST-GT and ST groups, measured at 60°, 90°, and 105° or 60°/s and 180°/s. No difference in standing nee flexion angle between ST-GT and ST groups.
Barenius *et al* [60], 2013	Retrospective study	No difference in isokinetic strength deficit between ST-GT and ST groups, at 20°, and 90° measured at 60°/s. No difference in isometric strength deficit between ST-GT and ST groups at 90°.
Lipscomb *et al* [61], 1982	Retrospective study	No difference in isokinetic strength deficit between ST-GT and ST groups, measured at 60°/s and 240°/s.

ST-GT: Semitendinosus and gracilis; ST: Semitendinosus; RCT: Randomized control trial; KOOS: Knee osteoarthritis and outcomes score.

Most studies assessed the strength deficit with isokinetic testing which was done in a sitting position while the hip was 90º flexed, a position that did not allow the ST and GT muscles to contract concentrically to produce knee flexion where a deficit could be spotted. Another explanation is that the isokinetic peak torque is usually measured at shallow angles. Here, knee flexion is elicited mostly by biceps femoris contraction, while the semitendinosus and gracilis muscle function is best evaluated at deeper angles[47]. In contrast, a reported strength deficit was elicited by Ardern *et al*[59] as a result of poor rehabilitation or early assessment, where the muscles have not recovered fully.

Despite the significance in hamstring strength, the previously mentioned studies reported no difference in subjective patient-reported outcome scores[46-49,55-60]. In addition, Hu *et al*[51] found a significant difference in the pain section of the knee injury and osteoarthritis outcome score. This can be attributed to the fact that the strength deficit is only observed in such deep angles and is not utilized by most people in their daily activities and is specifically used by athletes in gymnastics, judo, and wrestling (Table 3)[46,47,52].

GRAFT FIXATION

Currently, there are many methods for femoral-sided graft fixation in ACL reconstruction. They can be categorized into two main types: intra-tunnel fixation (interference screw) and extra tunnel fixation (cortical fixation devices or femoral loops). Fixation of soft tissue grafts is generally considered a weak point early in the postoperative course after ACL reconstruction[62]. Therefore, many different devices have been developed for soft-tissue femoral fixation[63]. Despite numerous options, the gold standard for femoral fixation has not yet been identified[63].

Suspensory fixation

Fixation methods can be categorized into compression, expansion, and suspension. Suspensory devices can be subdivided into cortical (metal plates with or without suture loops), cancellous, and corticocancellous devices[64]. Suspensory fixation devices can maximize the amount of graft in the femoral tunnel, thereby improving the outcomes of ACL reconstruction. Suspensory devices commonly feature a button that rests on the cortex of the femur and a loop that holds the folded soft tissue ACL graft in position until healing can occur[65-68]. This technique can avoid common problems that occur with interference screw fixation, such as divergent screw placement, laceration of sutures or grafts by screw threads, and increasing difficulty of revision surgery in the presence of screws[69].

Interference screw fixation

Because of its capacity to resist cyclic movements, one of the most efficient fixation devices are interference screws. The interference screw is a conical threaded device inserted into the bone tunnel, compressing the graft against the tunnel walls, and fixing it in the desired position. Although it is more commonly used on the tibial side; this screw can also be used for femoral fixation. Interference screws may be composed of metals or bioabsorbable materials[70]. A review article by Debieux *et al*[70] showed no difference in self-reported knee function and patients' postoperative activity levels when comparing bioabsorbable interference screws with metallic interference screws. However, bioabsorbable screws may be associated with overall treatment failures, including implant breakage during surgery.

Suspensory fixation versus interference screw fixation

There is no consensus on the best method to achieve hamstring autograft fixation during ACL reconstruction. Intra-tunnel fixation methods predominantly rely on the use of metal or bioresorbable interference screws. Extra-tunnel fixation methods rely on buttons, staples, or washer-post combinations placed outside the tunnel over the adjacent cortical bone surface[71]. Based on the literature review, each fixation has its own advantages and disadvantages for achieving early and long-term successful ACL reconstruction. Regarding the incidence of graft lengthening under cyclical loads after ACL reconstruction, Boutsiadis *et al*[72] assessed anterior knee laxity following primary ACLR. They found that the use of an adjustable loop suspensory fixation device for femoral fixation was associated with noninferior postoperative anterior knee laxity results compared with interference screw fixation at a minimum 2-years' follow-up. The operative pivot shift was the only significant risk factor for postoperative residual anterior knee laxity > 3 mm.

Regarding tunnel widening, a meta-analysis comparing the clinical results of the all-inside (ACLR) technique using suspensory cortical button fixation to a whole tibial tunnel drilling technique with interference screw fixation has shown that all-inside ACLR with suspensory cortical button fixation was not clinically superior in terms of functional outcomes, knee laxity measured with an arthrometer, or re-rupture rate. However, the advantage of using suspensory cortical button fixation is the ability to utilize a thicker graft and a lower rate of tibial tunnel widening[73]. In addition, Baumfeld *et al*[74] found significantly more femoral tunnel widening associated with the endobutton suspensory fixation system compared to double cross-pin fixation in the tunnel. However, they found a significant difference in the amount of tibial tunnel widening between the groups in this study[74]. A prospective comparative study by Sabat *et al*[75] compared the incidence of tunnel widening in patients who underwent ACL reconstruction with a quadrupled hamstring graft using either endobutton CL or Transfix on the femoral tunnel side and bioabsorbable interference screws in the tibial tunnel using computed tomography scans. Femoral tunnel widening was significantly lower in the Transfix group than in the EndoButton group. Regarding tunnel drilling techniques, Saygi *et al*[76] investigated the effect of tunnel undersizing (tight fit ACL reconstruction technique) on tunnel widening and overall clinical outcomes compared with conventional ACL reconstruction techniques. They concluded that undersized drilling might be preferred when using button fixation to reduce tunnel widening and improve clinical satisfaction.

Each fixation device has biomechanical properties that have been demonstrated in several studies. Shen *et al*[77] compared cross-pin to endobutton-CL femoral fixation and found that they are equally strong and safe fixation options for ACL reconstruction. However, cross-pin fixation has significantly less displacement of the femur-graft-tibia complex than endobutton-CL fixation in response to the cyclic loading test. Thus, it could be considered when early aggressive rehabilitation following ACL reconstruction is required. Milano *et al*[64] found that corticocancellous suspension fixation obtained

Table 4 Hamstring graft fixation techniques: summary of results

Graft fixation		
Ref.	**Study design**	**Results/conclusion**
Boutsiadis *et al* [72], 2018	Cohort study; level of evidence, 3	No difference in postoperative anterior knee laxity at a minimum 2 yr follow-up between interference screw and ALSF device for femoral fixation. The preoperative pivot shift is the only significant risk factor for postoperative residual anterior knee laxity more than 3 mm.
Shanmugaraj *et al*[81], 2020	Systematic review and meta-analysis	No significant differences in complication rates between femoral press-fit and femoral metal interference screw fixation. Press-fit fixation had significant improvements in functional outcome scores postoperatively and had significantly reduced postoperative bone tunnel enlargement compared to bioabsorbable fixation.
Debieux *et al* [70], 2016	Review	No difference in self-reported knee function and levels of activity between bioabsorbable and metallic interference screws. Bioabsorbable screws may be associated with more overall treatment failures, including implant breakage during surgery.
Han *et al*[62], 2012	Level II, systematic review of level I and II studies	At a minimum of 2 yr follow-up, comparable outcomes based on objective IKDC, Lysholm knee scale, and Tegner activity level survey results were found, as well as anterior knee joint laxity measurements between intra-tunnel and extra-tunnel fixation. Intra-tunnel fixation began jogging/running earlier than patients who received extra-tunnel fixation. However, return to sports timing was comparable between the groups.
Hu *et al*[80], 2017	Systematic review and meta-analysis	The significantly decreased instrumented side-to-side anterior–posterior laxity difference achieved by cross-pin transfixation appears to be of limited clinical significance when compared with interference screw fixation in primary hamstring ACLR.
Fu *et al*[73], 2020	Systematic review and meta-analysis	Suspensory cortical button fixation was not clinically superior to interference screw fixation in functional outcomes, knee laxity measured with arthrometer, or re-rupture rate. The advantage of using suspensory cortical button fixation was that a thicker graft could be used for reconstruction, and brought less tibia tunnel widening compared with bioabsorbable interference screw fixation.
Saccomanno *et al*[63], 2014	Systematic review of randomized controlled trials	There are no short- to medium-term differences in knee-specific outcome measures between cortical button femoral graft fixation and suspensory transfemoral fixation In addition, radiological evidence of tunnel widening does not seem to affect short- to medium-term clinical outcomes.
Speziali *et al* [79], 2014	Systematic review of level I and II therapeutic studies	Side-to-side anterior-posterior tibial translation was 1.9 ± 0.9, 1.5 ± 0.9, 1.5 ± 0.8, 2.2 ± 0.4 mm for metallic interference screw, bioabsorbable screw, cross-pin and suspensory device, respectively. Rate of failure was 6.1%, 3.3%, 1.7% and 1.2% for bioabsorbable interference screw, metallic interference screw, cross-pin and suspensory device, respectively.
Baumfeld *et al* [74], 2008	Retrospective review	There was significantly more femoral tunnel widening associated with the use of the endobutton suspensory fixation system compared to the use of double cross-pins fixation.
Milano *et al*[64], 2006	Biomechanical analysis	Corticocancellous suspension fixation offer the best results in terms of graft elongation, fixation strength, and stiffness. Cancellous suspension fixation was homogeneous with other suspension fixation mechanisms but significantly weaker. Interference screws, both metallic and absorbable, showed low failure load but greatest graft elongation.
Sabat *et al*[75], 2011	Level II, prospective comparative study	Femoral tunnel widening was significantly less in the Transfix group compared with the endobutton group.
Saygi *et al*[76], 2015	Therapeutic case series, level IV	Undersize drilling technique is preferred in button fixation in order to reduce tunnel widening and improve clinical satisfaction.
Shen *et al*[77], 2008	Biomechanical comparison study	The cross-pin fixation is a good option for early aggressive rehabilitation following ACL reconstruction due to has significantly less displacement of femur–graft–tibia complex than that of endobutton-CL fixation in response to the cyclic loading test.
Vertullo *et al* [78], 2019	Controlled laboratory study	The suspensory fixation constructs exhibited small yet statistically significant biomechanical differences among each other. Tibial screw fixation had lower ultimate failure load and higher total elongation.

ALSF: Adjustable-loop suspensory fixation; IKDC: International Knee Documentation Committee; ACLR: Anterior cruciate ligament rupture; ACL: Anterior cruciate ligament; CL: Cruciate ligament.

with transcondylar devices offered the best results in terms of graft elongation, fixation strength, and stiffness. Cancellous suspension fixation was homogeneous with other suspension fixation mechanisms but was significantly weaker. Interference screws, both metallic and absorbable, showed a low failure load but the greatest graft elongation. They concluded that the mechanical behavior of cortical suspension fixation was strictly correlated with the area of the contact surface between the hardware and cortical bone and the structural properties of the implant. Vertullo *et al*[78] conducted a biomechanical study comparing quadrupled tendon graft constructs with adjustable loop suspensory fixation to four-strand graft constructs secured with screws and a femoral fixed-loop device. They found small, yet significant, biomechanical differences between the different techniques. In addition, they found that tibial screw fixation resulted in a lower ultimate failure load and higher total graft elongation. Another study compared the different fixation techniques for ACLR. On the femoral side, a cross-pin, a metallic interference screw, a bioabsorbable interference screw, and a suspensory device were used in 32.3%, 27.3%, 24.8%, and 15.5% of the patients, respectively. On the tibial side, a metallic interference screw, a bioabsorbable interference screw, a screw and plastic sheath, a screw post, and a cross-pin were used in 38.7%, 31%, 15.7%, 12.8%, and 1.7% of the patients, respectively. The side-to-side anterior–posterior tibial translation was 1.9 ± 0.9, 1.5 ± 0.9, 1.5 ± 0.8, and 2.2 ± 0.4 mm for metallic interference screw, bioabsorbable screw, cross-pin, and suspensory device, respectively. The rate of failure was 6.1%, 3.3%, 1.7%, and 1.2% for the bioabsorbable interference screw, metallic interference screw, cross-pin, and suspensory device, respectively. Two-thirds of the patients achieved good-to-excellent clinical outcomes. Several pitfalls that affect current fixation techniques, such as graft tensioning and graft tunnel motion, remain unaddressed[79]. Moreover, Saccomanno *et al*[63] compared the cortical button with transfemoral suspensory fixation. They suggested that there were no short- to medium-term differences in the knee-specific outcome measures. In contrast, a meta-analysis by Hu *et al*[80] found a decrease in instrumented side-to-side anteroposterior laxity when cross-pin transfixation was used. However, the difference appears to have limited clinical significance compared with interference screw fixation. In addition, a 2-year clinical outcome study found that patients who underwent ACL reconstruction with intra-tunnel or extra-tunnel fixation had comparable results based on objective IKDC, Lysholm knee scale, Tegner activity level survey, anterior knee joint laxity measurements, and time to resume sports. Patients who received intra-tunnel fixation began full weight-bearing, jogging, and running earlier than patients who received extra-tunnel fixation[62]. Finally, a meta-analysis showed that the overall graft failure and revision rates with press-fit fixation for ACLR were low. There were no significant differences in the complication rates between patients who underwent femoral press-fit or femoral metal interference screw fixation. Patients who underwent press-fit fixation for ACLR had significant improvements in functional outcome scores post-operatively and significantly lower postoperative bone tunnel enlargement than patients who underwent bioabsorbable fixation. Thus, early evidence suggests that press-fit fixation is a good option for patients undergoing ACLR (Table 4)[81].

CONCLUSION

Multiple surgical maneuvers and approaches have been reported to avoid complications when reconstructing a ruptured ACL. For a hamstring tendon autograft, a shorter oblique anteromedial incision has been suggested to reduce the incidence of local neurological injuries compared to that with a longer vertical incision. The posteromedial harvesting approach is associated with fewer complications and better cosmetic outcomes. Sparing the gracilis tendon when harvesting the hamstring tendon can reduce the strength deficit postoperatively at deeper angles utilized by athletes. Several hamstring autograft fixation methods are available, but the optimum method is yet to be determined. Further studies are required to establish a safer surgical approach.

FOOTNOTES

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Country/Territory of origin: Saudi Arabia

ORCID number: Waleed Albishi 0000-0003-2088-4678; Bara Baltow 0000-0001-6236-9194; Nora Albusayes 0000-0003-2178-1961; Ameer A Sayed 0000-0002-8568-7467; Hamza M Alrabai 0000-0002-7486-1087.

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STANDARD AND CONSENSUS

Baishideng's *Reference Citation Analysis* database announces the first *Journal Article Influence Index* of 104 core journals and a list of high-quality academic journals in orthopedics

Jin-Lei Wang, Yu-Jie Ma, Li Ma, Na Ma, Diao-Mei Guo, Lian-Sheng Ma

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Peer-review report's scientific quality classification

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Grade B (Very good): B, B
Grade C (Good): 0
Grade D (Fair): 0
Grade E (Poor): 0

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Jin-Lei Wang, Yu-Jie Ma, Li Ma, Na Ma, Diao-Mei Guo, Lian-Sheng Ma, Baishideng Publishing Group Inc, Pleasanton, CA 94566, United States

Corresponding author: Lian-Sheng Ma, Doctor, Founder and CEO, Baishideng Publishing Group Inc, 7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, United States. l.s.ma@baishideng.com

Abstract

After three rounds of rigorous evaluation of core journals in orthopedics conducted by the *Reference Citation Analysis* (*RCA*) editorial team of Baishideng Publishing Group (Baishideng), the *RCA* database of Baishideng officially released the 2022 *Journal Article Influence Index* (2022 *JAII*) of 104 core journals and a list of high-quality academic journals in orthopedics, for the first time on August 9, 2022. The list of 104 core journals can be found at: https://www.referencecitationanalysis.com/SearchJournal. Among them, the highest 2022 *JAII* is 55.015 and the lowest is 3.076. This article introduces the 21 high-quality academic journals and describes the calculation method for the 2022 *JAII*, the evaluation process, and the inclusion principles for journals in the *RCA*. These steps are the underpinning of the *RCA*'s empirical journal academic evaluation service by which the digital platform addresses the needs of authors to select reliable journals for submission, readers to select high-quality literature for reading, and editors to track their own journal citation performance. As such, the *RCA* core journal list will serve as a useful Find-a-Journal tool. Any interested party is welcome to use this journal list and recommend it to their peers.

Key Words: *Reference Citation Analysis*; *Journal Article Influence Index*; Orthopedics; Journal list; Find a journal; Announcement

Core Tip: The *Reference Citation Analysis* (*RCA*) database of Baishideng Publishing Group officially released the 2022 *Journal Article Influence Index* (2022 *JAII*) of 104 core journals and the list of high-quality academic journals in orthopedics, for the first time. This article highlights the top 21 journals, describes the calculation method for the 2022 *JAII*, the evaluation process, and the inclusion principles of *RCA* journals. The *RCA* journal academic evaluation service platform addresses the needs of authors to select reliable journals for submission, readers to select high-quality literature for reading, and editors to track their own journal citation performance, effectively serving as a useful Find-a-Journal tool. You are welcome to use this journal list and recommend it to your peers.

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INTRODUCTION

We are very pleased to announce that the *Reference Citation Analysis* (*RCA*) database of Baishideng Publishing Group (Baishideng) has, for the first time, officially released the 2022 *Journal Article Influence Index* (2022 *JAII*) of 104 core journals in the field of orthopedics on August 9, 2022. The detailed information on these 104 core journals in orthopedics can be found at: https://www.referencecitation-analysis.com/SearchJournal.

RCA is an AI technology-based open multidisciplinary citation analysis database. As such, *RCA* will lead the development of wisdom, knowledge innovation, and emerging disciplines. The functions of *RCA* include: Find an Article (55334324), Find a Category (254), Find a Journal (14077), Find a Scholar (632), and Find an Academic Assistant (18) (Data collection: August 9, 2022)[1]. *RCA* updates its list of journals daily, according to relevant data including total number of articles, total citations, and the *JAII*. *RCA* acquires the newly released abstracts and references from Crossref and adds them to the *RCA* database weekly. *RCA* also acquires the abstracts and references released that year from Crossref and adds them to the *RCA* database monthly, and then updates the total number of articles, citations, and *JAII*. In this study, we introduce the top 21 journals ranked by the 2022 *JAII* from the total 104 core journals in the field of orthopedics included in *RCA*, the calculation method for the 2022 *JAII*, and the evaluation process and the inclusion principles of *RCA* journals.

TOP 21 JOURNALS RANKED BY THE 2022 *JAII* IN THE FIELD OF ORTHOPEDICS INCLUDED IN THE *RCA*

The *RCA* classifies academic journals with a *JAII* of 20.0 or above as high-quality academic journals, which will be highly recommended to authors and readers. There are 104 core journals in the field of orthopedics in the *RCA*, of which 21 were identified to be high-quality academic journals, accounting for 20.2%. These 21 high-quality academic journals, ranked by the *JAII* among the core journals in the field of orthopedics in the *RCA*, are described below.

2022 JAII and rankings of The Journal of Bone and Joint Surgery-American Volume

In the *RCA* database, the 2022 *JAII* for *The Journal of Bone and Joint Surgery-American Volume* is 55.015, ranking 1st among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 1110044 citations (1/104) and a total of 20177 articles (2/104) (Figure 1). For more information on *The Journal of Bone and Joint Surgery-American Volume*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of The American Journal of Sports Medicine

In the *RCA* database, the 2022 *JAII* for *The American Journal of Sports Medicine* is 52.976, ranking 2nd among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 589467 citations (4/104) and a total of 11127 articles (6/104) (Figure 2). For more information on *The American Journal of Sports Medicine*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of Spine

In the *RCA* database, the 2022 *JAII* for *Spine* is 44.570, ranking 3rd among 104 core journals in the field of

THE JOURNAL OF BONE AND JOINT SURGERY-AMERICAN VOLUME

Category Rank: Orthopedics

Total View: 5 (1/104)

Journal Article Influence Index: 55.015 (1/104)

Total Citations: 1110044 (1/104)

Cited by in F6Publishing: 643883 (1/104)

Total Articles: 20177 (2/104)

Number of Years: 74 (3/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 1 2022 *Journal Article Influence Index* and rankings of *The Journal of Bone and Joint Surgery-American Volume*. The image of the journal cover is originally from the home page of the journal: https://journals.lww.com/jbjsjournal/pages/default.aspx.

THE AMERICAN JOURNAL OF SPORTS MEDICINE

Category Rank: Orthopedics

Total View: 4 (6/104)

Journal Article Influence Index: 52.976 (2/104)

Total Citations: 589467 (4/104)

Cited by in F6Publishing: 460196 (3/104)

Total Articles: 11127 (6/104)

Number of Years: 46 (14/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 2 2022 *Journal Article Influence Index* and rankings of *The American Journal of Sports Medicine*. The image of the journal cover is originally from the home page of the journal: https://journals.sagepub.com/home/ajs.

orthopedics included in the *RCA*, with a total of 864839 citations (2/104) and a total of 19404 articles (3/104) (Figure 3). For more information on *Spine*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of European Cells & Materials

In the *RCA* database, the 2022 *JAII* for *European Cells & Materials* is 42.896, ranking 4th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 22735 citations (43/104) and a total of 530 articles (90/104) (Figure 4). For more information on *European Cells & Materials*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of Journal of Orthopaedic Research

In the *RCA* database, the 2022 *JAII* for *Journal of Orthopaedic Research* is 35.509, ranking 5th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 261809 citations (7/104) and a total of 7373 articles (14/104) (Figure 5). For more information on *Journal of Orthopaedic Research*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of Physical Therapy & Rehabilitation Journal

In the *RCA* database, the 2022 *JAII* for *Physical Therapy & Rehabilitation Journal* is 31.086, ranking 6th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 197801 citations (10/104) and a total of 6363 articles (20/104) (Figure 6). For more information on *Physical Therapy & Rehabilitation Journal*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of Arthroscopy

In the *RCA* database, the 2022 *JAII* for *Arthroscopy* is 29.982, ranking 7th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 285163 citations (5/104) and a total of 9511 articles (9/104) (Figure 7). For more information on *Arthroscopy*, please visit: https://www.referencecit-

SPINE

Category Rank: Orthopedics

Total View: 3 (31/104)

Journal Article Influence Index: 44.570 (3/104)

Total Citations: 864839 (2/104)

Cited by in F6Publishing: 558845 (2/104)

Total Articles: 19404 (3/104)

Number of Years: 46 (13/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 3 2022 *Journal Article Influence Index* and rankings of *Spine*. The image of the journal cover is originally from the home page of the journal: https://journals.lww.com/spinejournal/pages/issuelist.aspx.

EUROPEAN CELLS & MATERIALS

Category Rank: Orthopedics

Total View: 5 (2/104)

Journal Article Influence Index: 42.896 (4/104)

Total Citations: 22735 (43/104)

Cited by in F6Publishing: 11264 (46/104)

Total Articles: 530 (90/104)

Number of Years: 21 (50/104)

Peer-Reviewed Journal: Yes

Free Access: Open

DOI: 10.5312/wjo.v13.i10.891

Figure 4 2022 *Journal Article Influence Index* and rankings of *European Cells & Materials*. The image of the logo of AO Foundation is originally from the home page of the journal: http://www.ecmjournal.org/.

JOURNAL OF ORTHOPAEDIC RESEARCH

Category Rank: Orthopedics

Total View: 3 (17/104)

Journal Article Influence Index: 35.509 (5/104)

Total Citations: 261809 (7/104)

Cited by in F6Publishing: 204326 (5/104)

Total Articles: 7373 (14/104)

Number of Years: 39 (21/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 5 2022 *Journal Article Influence Index* and rankings of *Journal of Orthopaedic Research*. The image of the journal cover is originally from the home page of the journal: https://onlinelibrary.wiley.com/journal/1554527x.

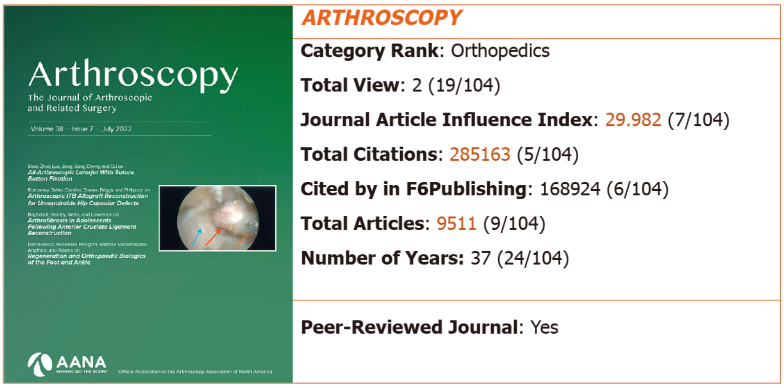
ationanalysis.com/SearchJournal.

2022 JAII and rankings of Osteoarthritis and Cartilage

In the *RCA* database, the 2022 *JAII* for *Osteoarthritis and Cartilage* is 28.691, ranking 8th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 194522 citations (12/104) and a total of 6780 articles (18/104) (Figure 8). For more information on *Osteoarthritis and Cartilage*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

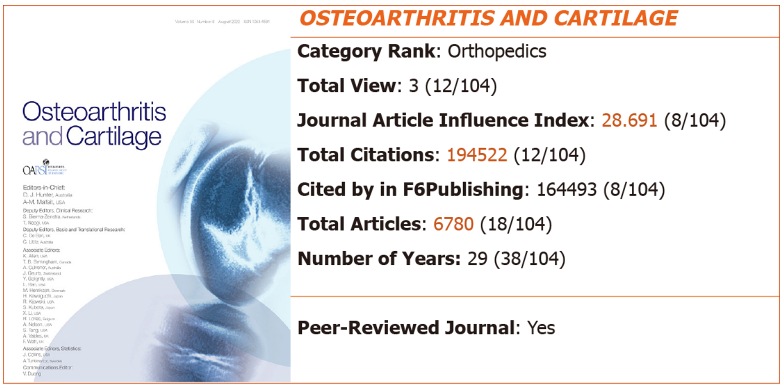
DOI: 10.5312/wjo.v13.i10.891

Figure 6 2022 *Journal Article Influence Index* and rankings of *Physical Therapy & Rehabilitation Journal*. The image of the journal cover is originally from the home page of the journal: https://academic.oup.com/ptj.



DOI: 10.5312/wjo.v13.i10.891

Figure 7 2022 *Journal Article Influence Index* and rankings of *Arthroscopy*. The image of the journal cover is originally from the home page of the journal: http://www.sciencedirect.com/science/journal/07498063.



DOI: 10.5312/wjo.v13.i10.891

Figure 8 2022 *Journal Article Influence Index* and rankings of *Osteoarthritis and Cartilage*. The image of the journal cover is originally from the home page of the journal: http://www.sciencedirect.com/science/journal/10634584.

2022 JAII and rankings of Journal of Shoulder and Elbow Surgery

In the *RCA* database, the 2022 *JAII* for *Journal of Shoulder and Elbow Surgery* is 27.384, ranking 9th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 195354 citations (11/104) and a total of 7134 articles (16/104) (Figure 9). For more information on *Journal of Shoulder and Elbow Surgery*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

JOURNAL OF SHOULDER AND ELBOW SURGERY

Category Rank: Orthopedics

Total View: 3 (13/104)

Journal Article Influence Index: 27.384 (9/104)

Total Citations: 195354 (11/104)

Cited by in F6Publishing: 117378 (12/104)

Total Articles: 7134 (16/104)

Number of Years: 30 (36/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 9 2022 *Journal Article Influence Index* and rankings of *Journal of Shoulder and Elbow Surgery*. The image of the journal cover is originally from the home page of the journal: http://www.sciencedirect.com/science/journal/10582746.

2022 JAII and rankings of Journal of Orthopaedic & Sports Physical Therapy

In the *RCA* database, the 2022 *JAII* for *Journal of Orthopaedic & Sports Physical Therapy* is 26.966, ranking 10th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 105707 citations (20/104) and a total of 3920 articles (27/104) (Figure 10). For more information on *Journal of Orthopaedic & Sports Physical Therapy*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of The Journal of The American Academy of Orthopaedic Surgeons

In the *RCA* database, the 2022 *JAII* for *The Journal of The American Academy of Orthopaedic Surgeons* is 25.946, ranking 11th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 86581 citations (24/104) and a total of 3337 articles (33/104) (Figure 11). For more information on *The Journal of The American Academy of Orthopaedic Surgeons*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of The Gait & Posture

In the *RCA* database, the 2022 *JAII* for *Gait & Posture* is 25.815, ranking 12th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 165136 citations (14/104) and a total of 6397 articles (19/104) (Figure 12). For more information on *Gait & Posture*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of The Journal of Hand Surgery

In the *RCA* database, the 2022 *JAII* for *The Journal of Hand Surgery* is 25.713, ranking 13th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 270686 citations (6/104) and a total of 10527 articles (8/104) (Figure 13). For more information on *The Journal of Hand Surgery*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of Clinical Biomechanics

In the *RCA* database, the 2022 *JAII* for *Clinical Biomechanics* is 25.387, ranking 14th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 124397 citations (18/104) and a total of 4900 articles (26/104) (Figure 14). For more information on *Clinical Biomechanics*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of Foot & Ankle International

In the *RCA* database, the 2022 *JAII* for *Foot & Ankle International* is 25.123, ranking 15th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 142573 citations (16/1041) and a total of 5675 articles (16/104) (Figure 15). For more information on *Foot & Ankle International*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of Clinical Orthopaedics and Related Research

In the *RCA* database, the 2022 *JAII* for *Clinical Orthopaedics and Related Research* is 23.901, ranking 16th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 612124 citations (3/104) and a total of 25611 articles (1/104) (Figure 16). For more information on *Clinical Orthopaedics and Related Research*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

JOURNAL OF ORTHOPAEDIC & SPORTS PHYSICAL THERAPY

Category Rank: Orthopedics
Total View: 3 (14/104)
Journal Article Influence Index: 26.966 (10/104)
Total Citations: 105707 (20/104)
Cited by in F6Publishing: 72730 (20/104)
Total Articles: 3920 (27/104)
Number of Years: 43 (18/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891 **Copyright** ©The Author(s) 2022.

Figure 10 2022 *Journal Article Influence Index* and rankings of *Journal of Orthopaedic & Sports Physical Therapy*. The image of the journal cover is originally from the home page of the journal: http://www.jospt.org/.

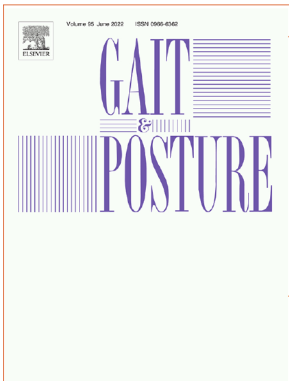
THE JOURNAL OF THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

Category Rank: Orthopedics
Total View: 2 (22/104)
Journal Article Influence Index: 25.946 (11/104)
Total Citations: 86581 (24/104)
Cited by in F6Publishing: 50765 (25/104)
Total Articles: 3337 (33/104)
Number of Years: 29 (39/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891 **Copyright** ©The Author(s) 2022.

Figure 11 2022 *Journal Article Influence Index* and rankings of *The Journal of The American Academy of Orthopaedic Surgeons*. The image of the journal cover is originally from the home page of the journal: https://journals.lww.com/jaaos.



GAIT & POSTURE

Category Rank: Orthopedics
Total View: 3 (15/104)
Journal Article Influence Index: 25.815 (12/104)
Total Citations: 165136 (14/104)
Cited by in F6Publishing: 98615 (14/104)
Total Articles: 6397 (19/104)
Number of Years: 29 (39/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891 **Copyright** ©The Author(s) 2022.

Figure 12 2022 *Journal Article Influence Index* and rankings of *Gait & Posture*. The image of the journal cover is originally from the home page of the journal: https://www.sciencedirect.com/journal/gait-and-posture.

2022 JAII and rankings of Acta Orthopaedica

In the *RCA* database, the 2022 *JAII* for *Acta Orthopaedica* is 23.437, ranking 17th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 35953 citations (34/104) and a total of 1534 articles (56/104) (Figure 17). For more information on *Acta Orthopaedica*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

THE JOURNAL OF HAND SURGERY

Category Rank: Orthopedics
Total View: 2 (21/104)
Journal Article Influence Index: 25.713 (13/104)
Total Citations: 270686 (6/104)
Cited by in F6Publishing: 112017 (13/104)
Total Articles: 10527 (8/104)
Number of Years: 46 (15/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 13 2022 *Journal Article Influence Index* and rankings of *The Journal of Hand Surgery*. The image of the journal cover is originally from the home page of the journal: http://www.sciencedirect.com/science/journal/03635023.

CLINICAL BIOMECHANICS

Category Rank: Orthopedics
Total View: 1 (88/104)
Journal Article Influence Index: 25.387 (14/104)
Total Citations: 124397 (18/104)
Cited by in F6Publishing: 67321 (21/104)
Total Articles: 4900 (26/104)
Number of Years: 36 (26/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 14 2022 *Journal Article Influence Index* and rankings of *Clinical Biomechanics*. The image of the journal cover is originally from the home page of the journal: https://www.sciencedirect.com/journal/clinical-biomechanics.

FOOT & ANKLE INTERNATIONAL

Category Rank: Orthopedics
Total View: 1 (89/104)
Journal Article Influence Index: 25.123 (154/104)
Total Citations: 142573 (16/104)
Cited by in F6Publishing: 82809 (15/104)
Total Articles: 5675 (23/104)
Number of Years: 28 (41/104)

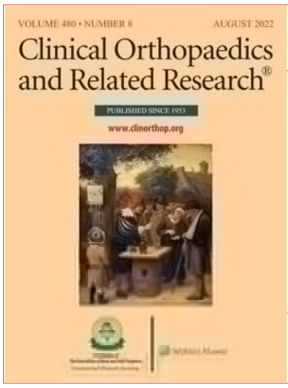
Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 15 2022 *Journal Article Influence Index* and rankings of *Foot & Ankle International*. The image of the journal cover is originally from the home page of the journal: https://journals.sagepub.com/home/fai.

2022 JAII and rankings of Knee Surgery Sports Traumatology Arthroscopy

In the *RCA* database, the 2022 *JAII* for *Knee Surgery Sports Traumatology Arthroscopy* is 22.713, ranking 18th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 172777 citations (13/104) and a total of 7607 articles (13/104) (Figure 18). For more information on *Knee Surgery Sports Traumatology Arthroscopy*, please visit: https://www.referencecitationanalysis.com/Search-Journal.



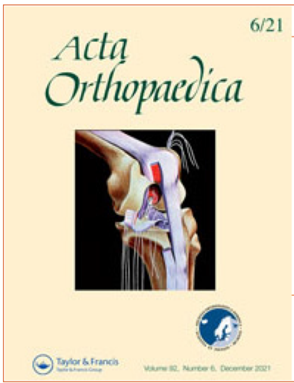
CLINICAL ORTHOPAEDICS AND RELATED RESEARCH

Category Rank: Orthopedics
Total View: 1 (90/104)
Journal Article Influence Index: 23.901 (16/104)
Total Citations: 612124 (3/104)
Cited by in F6Publishing: 407047 (4/104)
Total Articles: 25611 (1/104)
Number of Years: 59 (4/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 16 2022 *Journal Article Influence Index* and rankings of *Clinical Orthopaedics and Related Research*. The image of the journal cover is originally from the home page of the journal: https://journals.lww.com/clinorthop/pages/default.aspx.



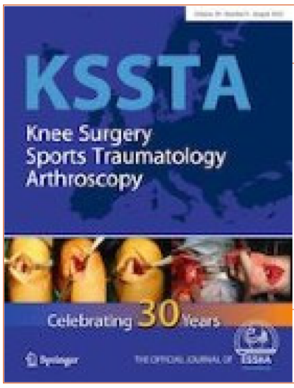
ACTA ORTHOPAEDICA

Category Rank: Orthopedics
Total View: 4 (3/104)
Journal Article Influence Index: 23.437 (17/104)
Total Citations: 35953 (34/104)
Cited by in F6Publishing: 31145 (29/104)
Total Articles: 1534 (56/104)
Number of Years: 34 (30/104)

Peer-Reviewed Journal: Yes
Free Access: Open

DOI: 10.5312/wjo.v13.i10.891

Figure 17 2022 *Journal Article Influence Index* and rankings of *Acta Orthopaedica*. The image of the journal cover is originally from the home page of the journal: https://www.tandfonline.com/journals/iort20.



KNEE SURGERY SPORTS TRAUMATOLOGY ARTHROSCOPY

Category Rank: Orthopedics
Total View: 1 (87/104)
Journal Article Influence Index: 22.713 (18/104)
Total Citations: 172777 (13/104)
Cited by in F6Publishing: 127770 (10/104)
Total Articles: 7607 (10/104)
Number of Years: 29 (40/104)

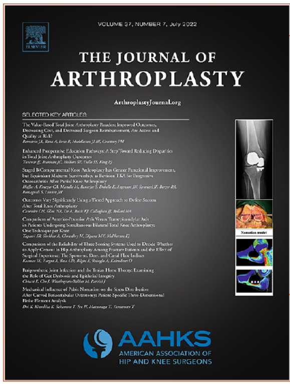
Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 18 2022 *Journal Article Influence Index* and rankings of *Knee Surgery Sports Traumatology Arthroscopy*. The image of the journal cover is originally from the home page of the journal: https://Link.springer.com/journal/167.

2022 JAII and rankings of The Journal of Arthroplasty

In the *RCA* database, the 2022 *JAII* for *The Journal of Arthroplasty* is 22.683, ranking 19th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 257022 citations (8/104) and a total of 11322 articles (5/104) (Figure 19). For more information on *The Journal of Arthroplasty*, please visit: https://www.referencecitationanalysis.com/SearchJournal.



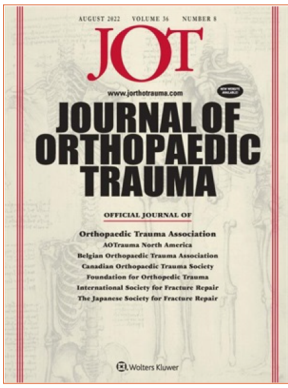
THE JOURNAL OF ARTHROPLASTY

Category Rank: Orthopedics
Total View: 2 (26/104)
Journal Article Influence Index: 22.683 (19/104)
Total Citations: 257022 (8/104)
Cited by in F6Publishing: 167335 (7/104)
Total Articles: 11331 (5/104)
Number of Years: 36 (25/104)

Peer-Reviewed Journal: Yes
Free Access: Open

DOI: 10.5312/wjo.v13.i10.891

Figure 19 2022 *Journal Article Influence Index* and rankings of *The Journal of Arthroplasty*. The image of the journal cover is originally from the home page of the journal: http://www.sciencedirect.com/science/journal/08835403.



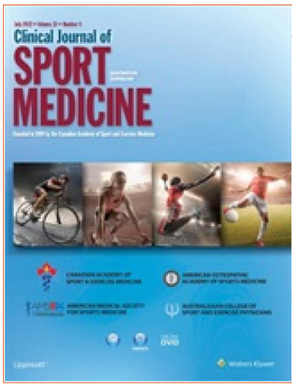
JOURNAL OF ORTHOPAEDIC TRAUMA

Category Rank: Orthopedics
Total View: 1 (59/104)
Journal Article Influence Index: 22.363 (20/104)
Total Citations: 137263 (17/104)
Cited by in F6Publishing: 75584 (18/104)
Total Articles: 6138 (22/104)
Number of Years: 35 (28/104)

Peer-Reviewed Journal: Yes

DOI: 10.5312/wjo.v13.i10.891

Figure 20 2022 *Journal Article Influence Index* and rankings of *Journal of Orthopaedic Trauma*. The image of the journal cover is originally from the home page of the journal: https://journals.lww.com/jorthotrauma/pages/issuelist.aspx.



CLINICAL JOURNAL OF SPORT MEDICINE

Category Rank: Orthopedics
Total View: 1 (65/104)
Journal Article Influence Index: 21.471 (21/104)
Total Citations: 55095 (27/104)
Cited by in F6Publishing: 30531 (31/104)
Total Articles: 2566 (41/104)
Number of Years: 31 (33/104)

Peer-Reviewed Journal: Yes
Free Access: Open

DOI: 10.5312/wjo.v13.i10.891

Figure 21 2022 *Journal Article Influence Index* and rankings of *Clinical Journal of Sport Medicine*. The image of the journal cover is originally from the home page of the journal: https://journals.lww.com/cjsportsmed/pages/issuelist.aspx.

2022 JAII and rankings of Journal of Orthopaedic Trauma

In the *RCA* database, the 2022 *JAII* for *Journal of Orthopaedic Trauma* is 22.363, ranking 20th among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 137263 citations (17/104) and a total of 6138 articles (22/104) (Figure 20). For more information on *Journal of Orthopaedic Trauma*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

2022 JAII and rankings of Clinical Journal of Sport Medicine

In the *RCA* database, the 2022 *JAII* for *Clinical Journal of Sport Medicine* is 21.471, ranking 21st among 104 core journals in the field of orthopedics included in the *RCA*, with a total of 55095 citations (27/104) and a total of 2566 articles (41/104) (Figure 21). For more information on *Clinical Journal of Sport Medicine*, please visit: https://www.referencecitationanalysis.com/SearchJournal.

RCA'S MISSION

The mission of *RCA* is to provide a high-quality academic article evaluation service platform for various categories. At present, there are many evaluation methods for academic articles, but their calculation methods are complicated. The *RCA* is a new method of evaluating the quality of academic articles, which allows academic evaluation of journals, scholars, institutions, drugs, medical devices, and publishers based on the *JAII* of each article in the citation analysis database, thus greatly enriching the academic evaluation systems across different categories and guiding the healthy development of the academic community[2].

OPENNESS AND TRANSPARENCY OF RCA EVALUATION

RCA is unique in its objective, impartial, fair, and transparent release of citation analysis data of important academic journals to authors and readers, including evaluation data, evaluation indices, evaluation methods, and evaluation results, in order to ensure the reliability of academic evaluation[2].

CALCULATION METHOD FOR 2022 *JAII*

The 2022 *JAII*, calculated as Total citations/Total articles, is not a 2-year or 5-year average of citations, but is an average of citations for all articles since the journal was assigned its DOI number. Article types are not only limited to original articles and review articles, but for all types of articles. In this way, it is a more objective, fair, and transparent calculation of the academic influence index of an academic journal. Furthermore, the journal list itself is evaluated dynamically, with its bibliographic metrics being updated daily, including total number of articles, total citations, and *JAII*[2].

EVALUATION PROCESS OF *RCA* JOURNALS

The journals included in the *RCA* core journal list need to undergo three rounds of strict evaluation. The evaluation process is as follows[2]:

First-round evaluation: The basic information on the journal is verified, including Journal Name, Abbreviated Title, Print ISSN, Online ISSN, Language, Category, Peer-Reviewed Journal, Ownership, Publisher, Journal Website, Editorial Board Members, Submit a Manuscript, and Indexed by.

Second-round evaluation: The activity of the journal is verified, including Total Articles, Total Citations, Cited by in F6Publishing, and the *JAII*.

Third-round evaluation: Based on the reliability of journal information, the activity of publication data, whether the journal is a peer-reviewed journal or not, and *JAII*, the editorial team evaluates every journal, makes the decision to accept or reject the journal, and creates a list of core journals by category. The function of the list of core academic journals is to classify journals according to categories and rank them according to various bibliometrics, including Total Views, *JAII*, Total Citations, Cited by in F6Publishing, Total Articles, and Number of Years.

INCLUSION PRINCIPLES OF *RCA* JOURNALS

The *RCA* editorial team of Baishideng conducted three rounds of rigorous evaluation of core journals in orthopedics. The resultant *RCA* core journal list for the field of orthopedics includes a total of 104 journals, among which the highest 2022 *JAII* is 55.015 and the lowest *JAII* is 3.076, the highest total number of citations is 1110044 and the lowest is 678, and the highest total number of articles is 612124 and the lowest is 164. The *RCA* core journal list does not include any journals with a *JAII* lower than 3.0. We implement dynamic evaluation inclusively for the *RCA* core journal list. Evaluation is initiated once an *RCA*-nonincluded journal receives a *JAII* over 3.0. Similarly, if a journal included in the *RCA* core journal list receives a *JAII* lower than 3.0, it will be excluded. The *RCA* core journal list is designed by publishers, scientific editors, and engineers for use by readers, authors, and editorial offices, and is free of charge to users[2].

Upon completion of the three rounds of rigorous evaluation of core journals in orthopedics by the *RCA* editorial team, all data in each journal are organized for public consumption according to category rank, including the 2022 *JAII*, total citations, cited by in F6Publishing, total articles, and the 2021 Journal Impact Factor™. All information in each journal, including Journal Name, Print ISSN, Online ISSN, Language, Free Access, Peer-Reviewed Journal, Ownership, Publisher, Journal Website, Editorial Board Members, Submit a Manuscript, and Indexed by, is made available in *RCA*. Moreover, the citations of each journal can be then ranked in *RCA* by the *Impact Index Per Article*, Cited by in Crossref, and Cited by in F6Publishing parameters. Results analysis available for each journal includes Year Published Analysis, Article Type Analysis, Journal Title Analysis, and Category Analysis. The references of each journal are also able to be refined by Year Published and Article Type. Each reference's citation information is displayed, including PMID, DOI, Cited by in Crossref, *Impact Index Per Article*, *RCA*, and Track Full Text[2].

CONCLUSION

The ultimate purpose of *RCA* is to provide an open, objective, fair, and reliable academic evaluation service platform for readers, authors, and journal editors, in order to address the needs of authors to select reliable journals for submission, readers to select high-quality literature for reading, and editors to track their own journal citation performance.

FOOTNOTES

Author contributions: Wang JL analyzed the data and drafted the manuscript; Ma YJ participated in the data collection; Ma LS revised the manuscript for important intellectual content; and all authors participated in manuscript revision.

Conflict-of-interest statement: The authors are all employees of the Baishideng Publishing Group Inc and declare that they have no other real or potential conflicts of interest to disclose.

Country/Territory of origin: United States

ORCID number: Jin-Lei Wang 0000-0002-5197-3051; Lian-Sheng Ma 0000-0002-1430-4844.

S-Editor: Wang JJ
L-Editor: Webster JR
P-Editor: Wang JJ

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World Journal of Orthopedics

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ISSN 2218-5836 (online)

ORIGINAL ARTICLE

Retrospective Cohort Study

Preoperative and postoperative risk factors for periprosthetic joint infection in primary total hip arthroplasty: A 1-year experience

Giuseppe Ferdinando Tella, Cesare Donadono, Francesco Castagnini, Barbara Bordini, Monica Cosentino, Michele Di Liddo, Francesco Traina

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Giuseppe Ferdinando Tella, Cesare Donadono, Francesco Castagnini, Michele Di Liddo, Francesco Traina, Ortopedia-Traumatologia e Chirurgia protesica e dei reimpianti d'anca e di ginocchio, IRCCS Istituto Ortopedico Rizzoli, Bologna 40125, Italy

Barbara Bordini, Monica Cosentino, Laboratorio di Tecnologia Medica, IRCCS Istituto Ortopedico Rizzoli, Bologna 40125, Italy

Corresponding author: Cesare Donadono, MD, Doctor, Ortopedia-Traumatologia e Chirurgia protesica e dei reimpianti d'anca e di ginocchio, IRCCS Istituto Ortopedico Rizzoli, Via Cesare Pupilli 1, Bologna 40125, Italy. c.donadono@gmail.com

Abstract

BACKGROUND

Periprosthetic joint infection (PJI) in primary total hip replacement (THR) is one of the most important threats in orthopedic surgery, so one important surgeon's target is to avoid or early diagnose a PJI. Although the incidence of PJI is very low (0.69%) in our department, with an average follow-up of 595 d, this infection poses a serious threat due to the difficulties of treatment and the lower functional outcomes after healing.

AIM

To study the incidence of PJI in all operations occurring in the year 2016 in our department to look for predictive signs of potential infection.

METHODS

We counted 583 THR for 578 patients and observed only 4 cases of infection (0.69%) with a mean follow-up of 596 d (min 30, max 1451). We reviewed all medical records to collect the data: duration and time of the surgery, presence, type and duration of the antibiotic therapy, preoperative diagnosis, blood values before and after surgery, transfusions, presence of preoperative drugs (in particularly anticoagulants and antiaggregant, corticosteroids and immunosuppressants), presence of some comorbidities (high body mass index, blood hypertension, chronic obstructive pulmonary disease, cardiac ischemia, diabetes, rheumatological conditions, previous local infections).

RESULTS

No preoperative, intraoperative, or postoperative analysis showed a higher incidence of PJI. We did not find any class with evident major odds of PJI. In our study, we did not find any border value to predict PJI and all patients had similar values in both groups (non-PJI and PJI). Only some categories, such as female patients, showed more frequency of PJI, but this difference related to sex was not statistically significant.

CONCLUSION

We did not find any category with a higher risk of PJI in THR, probably due to the lack of few cases of infection.

Key Words: Primary total hip replacement; Periprosthetic joint infection; Preoperative risk factors; Postoperative risk factors; Preoperative and postoperative blood value; Total hip arthroplasty

Core Tip: In this study, we evaluated the incidence of periprosthetic joint infection in all interventions occurring in the year 2016 at our department at IRCCS Istituto Ortopedico Rizzoli. We reviewed all operated patients to look for predictive signs of potential infection to explore methodological approaches that could better inform daily orthopedic practice. We reviewed the duration and time of surgery, presence, type and duration of antibiotic therapy, preoperative diagnosis, some blood values before and after surgery, transfusions, the presence of preoperative drugs, and the presence of some comorbidities.

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INTRODUCTION

Periprosthetic joint infection (PJI) in primary total hip replacement (THR) is one of the most important threats in orthopedic surgery. When it occurs, many types of treatment are proposed[1-7] and different studies have reported similar odds of healing[1,3,7]. In this study, we evaluated the incidence of PJI in all interventions occurring in the year 2016 at our department. We counted 583 primary THR in 578 patients. We observed only four cases of infection with a minimum of 20 d to a maximum of 390 d after the THR. We reviewed all operated patients trying to look for predictive signs of potential infection. We reviewed the duration and time of surgery, presence, type and duration of antibiotic therapy, preoperative diagnosis, blood value before and after surgery, transfusions, presence of preoperative drugs (in particularly anticoagulants and antiaggregant, corticosteroids and immunosuppressants), presence of some comorbidities (high body mass index [BMI], blood hypertension, chronic obstructive pulmonary disease [COPD], cardiac ischemia, diabetes, rheumatological conditions, previous local infections). We tried to identify some values to predict or early diagnose PJI analyzing all data collected from surgeries occurring in 1 year.

MATERIALS AND METHODS

With agreement of the ethics committee of the Rizzoli Orthopedic Institute (Bologna, Italy), we reviewed all patients who had undergone total hip replacement (THR) in 2016. Categorical data were analyzed with use of the Fisher's test and χ^2 test and continuous data with the *t*-test. Level of significance was set at 0.05. There were 583 THR on 578 patients. Only 4 cases reported PJI (0.69%) and were re-operated. We reviewed all medical records to collect the data. All of these patients were visited at the hospital and in all authorized external clinics with the presence of a Rizzoli's doctor for follow-up. We had a mean follow-up of 595 d (min 30, max 1451). There were 320 females 54.9% and 263 males 45.1%, with a mean age of 62.2 years (min 17, max 88). The mean age for the 4 patients with infection was 62.8 age (min 51, max 69) (P = 0.98, *t* test) and included 3 females and 1 male (P = 0.63, Fisher's test). Differences in frequencies of infection for different BMI groups were not statistically significant (P = 0.455; χ^2 test). All patients received preoperative antibiotic therapy, 564 with cefazolin 2 g (96.9%) and 18 with clindamycin (3.1%); one case was lost. In the PJI group, all patients were treated with cefazolin (P = 1.00, Fisher's test). Twenty-one patients underwent further antibiotic treatment (see Table 1) with

Table 1 Patients' characteristics according to periprosthetic joint infection

Covariate	Infection (yes)	Infection (not)	*P* value
Age, mean (min-max)	62.8 (51-69)	62.8 (17-88)	*P* = 0.98; T-test
Sex			
Female (%)	3 (75.0)	317 (54.7)	*P* = 0.63; Fisher's test
Male (%)	1 (25.0)	262 (45.3)	
BMI			
Underweight (%)	-	4 (0.7)	*P* = 0.455; χ^2 test
Normal (%)	1 (25.0)	208 (36.0)	
Overweight (%)	1 (25.0)	259 (44.8)	
Obese (%)	2 (50.0)	107 (18.5)	
Antibiotic therapy			
Cefazolin (%)	4 (100.0)	560 (96.9)	*P* = 1.00; Fisher's test
Clindamycin (%)	-	18 (3.1)	
Additional antibiotic doses			
Yes (%)	1 (25.0)	20 (3.5)	*P* = 0.137; Fisher's test
Not (%)	3 (75.0)	559 (96.5)	
Diagnosis			
Coxartrosis (%)	3 (75.0)	370 (97.6)	*P* = 1.00; Fisher's test
Dysplasia (%)	1 (25.0)	9 (2.4)	
Bearings			
Cer-cer (%)	4 (100.0)	522 (90.2)	*P* = 0.001; χ^2 test
Cer-pol (%)	-	8 (1.4)	
Met-pol (%)	-	49 (8.5)	
Steroid			
Yes (%)	1 (25.0)	14 (2.4)	*P* = 0.1; Fisher's test
Not (%)	3 (75.0)	562 (97.6)	
Immunosuppressants			
Yes (%)	-	13 (2.3)	*P* = 0.1; Fisher's test
Not (%)	4 (100.0)	564 (97.7)	
Antiaggregant drugs			
Yes (%)	1 (25.0)	116 (20.1)	*P* = 1.00; Fisher's test
Not (%)	3 (75.0)	460 (79.9)	
Local surgery before the operation			
Yes (%)	-	66 (11.5)	*P* = 1.00; Fisher's test
Not (%)	4 (100.0)	507 (88.5)	
COPD			
Yes (%)	-	78 (13.5)	*P* = 1.00; Fisher's test
Not (%)	4 (100.0)	500 (86.5)	
Chronic renal insufficiency			
Yes (%)	1 (25.0)	20 (3.5)	*P* = 0.137; Fisher's test
Not (%)	3 (75.0)	558 (96.5)	
Preexisting heart ischemic conditions			

Yes (%)	1 (25.0)	51 (8.8)	P = 0.313; Fisher's test
Not (%)	3 (75.0)	527 (91.2)	
Diabetes			
Yes (%)	-	44 (7.6)	P = 1.00; Fisher's test
Not (%)	4 (100.0)	533 (92.4)	
Rheumatological conditions			
Yes (%)	-	12 (2.1)	P = 1.00; Fisher's test
Not (%)	4 (100.0)	565 (97.9)	
Previously local septic conditions			
Yes (%)	-	6 (1.0)	P = 1.00; Fisher's test
Not (%)	4 (100.0)	571 (99.1)	
Blood transfusion			
Yes (%)	1 (25.0)	98 (16.9)	P = 1.00; Fisher's test
Not (%)	3 (75.0)	468 (80.8)	
Prosthesis fixation			
Uncemented (%)	4 (100.0)	570 (98.4)	P = 1.00; Fisher's test
Cemented stem and uncemented cup (%)	-	9 (1.6)	
Time of intervention			
(07-12) (%)	4 (100.0)	442 (76.3)	P = 0.578; Fisher's test
(12-19) (%)	0	137 (23.7)	

Cer-Cer: Ceramic on ceramic; Cer-pol; Ceramic on polyethylene; COPD: Chronic obstructive pulmonary disease; Cup: Met-pol: Metal on polyethylene.

different types of drugs and doses, of whom one patient had a PJI. In the PJI group (see Table 1), 3 patients underwent THR for primary arthrosis and 1 for hip dysplasia (P = 1.00, Fisher's test). Regarding the bearing, 526 were ceramic on ceramic (90.2%), 8 were ceramics on polyethylene (1.4%), and 49 were metal on polyethylene (8.4%). In the PJI group, they were all ceramic on ceramic (P = 0.001, χ^2 test). Five hundred and seventy stems were uncemented (98.4%) and only nine were cemented (1.6%). All PJIs occurred in the prosthesis with uncemented stems. (P = 1.000, Fisher's test). Regarding the use of drugs, 565 patients (97.4%) did not use steroids and only 15 (2.6%) used them before surgery. In the PJI group, only 1 patient used drugs before intervention (P = 0.1, Fisher's test). Five hundred and sixty-eight patients (97.8%) did not use immunosuppressants and only thirteen (2.2%) used them before and after the intervention. In the PJI group, no patient used immunosuppressants (P = 0.1, Fisher's test). Four hundred and sixty-three patients (79.8%) did not use antiaggregant and one hundred and seventeen (20.2%) used it before intervention. In the PJI group, only 1 was using antiaggregant (P = 1.000, Fisher's test). Five hundred and eleven patients (88.6%) did not have local surgery before the operation and sixty-six did (11.4%). In the PJI group, none of the patients did (P = 1.000, Fisher's test). Considering the preoperative hemoglobin value, we found that it was less than 12 g/dL in 25 cases (4.3%) and higher in 557 cases (95.7%). In the PJI group, all patients had a value superior to 12 g/dL.

We considered the incidence of PJI in relation to COPD, and there were 504 cases (86.6%) without lung disease and 78 with COPD (13.4%). PJI occurred in all patients without COPD (P = 1.000, Fisher's test). Five hundred and sixty-one patients (96.4%) did not have chronic renal insufficiency (CRI) and twenty-one had CRI (3.6%); data were missing for one patient. In the PJI group, 3 patients suffered from CRI and 1 did not (P = 0.137, Fisher's test).

Considering the incidence of PJI in relation to preexisting heart ischemic conditions, 530 patients (91.1%) did not have heart disease before and after the operation, 52 patients (8.9%) had different degrees of ischemic condition preoperatively. For 1 patient, the data were missing. Only 1 patient with this comorbidity had PJI and the other 3 did not have any heart disease (P = 0.313, Fisher's test). Considering the incidence of PJI in relation of diabetes, there were 537 cases (92.4%) without diabetes and 44 with the disease (7.6%). The data were missing for 2 patients. We were not able to recognize the degree and type of the disease. PJIs occurred in all patients without diabetes (P = 1.000, Fisher's test). Considering the incidence of PJI in relation to rheumatological conditions, there were 569 cases (97.9%) without and 12 with rheumatological disease (2.1%). The data were missing for 2 patients. PJI patients did not suffer from/have any rheumatological condition (P = 1.000, Fisher's test). Considering the incidence of PJI in relation to previously local septic conditions, there were 575 cases (99%) without previous septic conditions and 6 with them (1%). The data were missing for 2 patients. PJI was present in all patients without previous septic conditions (P = 1.000, Fisher's test). Laboratory data are summarized in Table 1.

For the erythrocyte sedimentation rate (ESR) value, the preoperative mean was 11.1 mm (the data were missing in 2 cases): 11.1 mm for all cases without PJI and 11 mm for cases with PJI. For the C-reactive protein (CRP) value, the preoperative mean was 0.9 mg/dL (data were missing in 16 cases): 0.9 mg/dL for all cases without PJI and 0.5 mg/dL for cases with PJI. For the WBC count, the preoperative mean was 7199.5 × 10^6/L (the data were missing in 20 cases): 7192.55 × 10^6/L for all cases without PJI and 8177.55 × 10^6/L for cases with PJI. For the Hb value, the preoperative mean was 13.9 g/dL (the data were missing in 16 cases): 13.9 g/dL for all cases without PJI and 14.6 g/dL for cases with PJI (see Table 2).

We analyzed the same parameters in the postoperative period: the day after surgery, the last day of hospitalization, and a random day between these days. We did not have these three parameters for all patients and many others had more than three values. In the last case, we picked up the lowest data. Analyses of the data showed that the average Hb value the day after the operation was 11.1 g/dL: 11.1 g/dL for all cases without PJI and 11.0 g/dL for the 4 cases with PJI (the data were missing for 2 patients). The average WBC count was 9804.5 × 10^6/L: 9821.5 × 10^6/L for cases without PJI and 7360.0 × 10^6/L for cases with PJI (see Table 2).

Analyses of the data showed that the average Hb value of the intermediate sample was 10.0 g/dL: 10.0 g/dL for all cases without PJI and 10.6 g/dL for the 4 cases with PJI (the data were missing for 33 patients). The intermediate average of WBC count was 8984.9 × 10^6/L: 8997.6 × 10^6/L for cases without PJI and 7257.5 × 10^6/L for cases with PJI. The samples on the last day of hospitalization showed that the average Hb value for all patients was 10.1 g/dL: 10.1 g/dL for all cases without PJI and 10.7 g/dL for the 4 cases with PJI. On the last day of hospitalization, the average WBC count was 7759.1 × 10^6/L: 7764.4 × 10^6/L for cases without PJI and 7764.4 × 10^6/L for cases with PJI (data were missing in 42 patients) (See Tables 1 and 2).

Regarding blood transfusion, 450 patients (77.2%) did not have a blood transfusion, 3 of whom were part of the PJI group, 133 (22.8%) had one or more homologous blood sack, only 1 had PJI (P = 1.000, Fisher's test). The average time of operation was 01:17:42 (min 00:37:00 max 04:03:00): 01:17:38 (min 00:37:00 max 04:03:00) for patients without PJI and 01:26:45 (min 00:56:00 max 02:31:00) for patients with PJI. Four hundred and forty-six patients (76.5%) were operated on between 07:00 and 12:00 and 137 (23.5%) between 12:00 to 19:00. All PJI patients were operated from 07:00 to 12:00.

RESULTS

Infections are classified according to their temporal appearance[4], even though many systems proposed are not always accepted[8]. We defined acute infection as symptoms lasting less than 4 wk, and chronic as lasting more than 4 wk. Many kinds of treatments have been proposed with different indications and results[2-6]. All surgeons agree with the difficulties of the different approaches to treat a PJI (surgery and drugs with multidisciplinary approaches)[4-6,9]. For these reasons, we reviewed all cases of THR treated in 2016 in our Department of Orthopedic Surgery to identify preoperative and postoperative signs to predict a PJI.

All cases were operated on by no more than 10 different surgeons at our department in the same operating room with laminar airflow. All cases underwent the same type of surgery: lateral approach with detachment of the gluteus minimus and medius and reconstruction of the hip capsule. All cases had the drainage removed within 24 h after surgery. Standard procedures of antibiotic prophylaxis were followed: cefazolin 2 g in most of the patients and clindamycin 600 mg in allergic patients.

Four patients had a PJI: two within 30 d, one 6 mo later, and one 13 mo later. All patients were surgically treated with deep or superficial debridement first[2]. One of these patients underwent a two-stage revision after this surgical procedure. Analyzing sex, we founded that PJI incidence was higher in females than men (see Table 1), but data were not statistically significant as in many other studies[10]. Regarding age (see Table 1), no differences were observed between the two groups, as previously reported[11].

Analyzing antibiotic therapy (see Table 1), all patients with PJI were treated with single-dose cefazolin 2 g before surgery. After surgery, many patients had postoperative antibiotic treatment (see Table 1), 1 of whom developed a PJI. Even in this case, we did not find a difference between the two groups. Regarding the indications that led to the operation, no category showed a higher risk than another. Analyses of the bearings and different types of prostheses did not show a difference in the incidence of PJI. Analyses of the use of drugs such as steroids, immunosuppressors, and anticoagulants showed that PJI did not have a higher incidence in any patient, which disagrees with a previous study [12]. We did not find differences in Hb value and WBC count between the two groups of patients (see Table 2). We did not analyze the CRP and ESR due to the lack of values for many patients.

Table 2 Blood values according to periprosthetic joint infection

	Infection (yes)				Infection (not)			
	Pre	T1	T2	Last	Pre	T1	T2	Last
Hemoglobin	14.6	11.0	10.6	10.7	13.9	11.1	10.0	10.1
White blood cells	8177.5	7360.0	7257.5	7040.0	7192.5	9821.5	8997.6	7764.4

Data are means.

In the analysis of blood transfusions in relation to PJI, 133 patients were transfused with one or more blood sacks, and 450 did not receive any transfusion. PJI occurred in 3 of the non-transfused patients and in 1 transfused patient. Analyses of the blood transfusions showed a higher incidence of PJI in transfused patients but it was not statistically significant, in disagreement with a previous study[13]. Analyzing the time of surgery, we divided the patients in two groups: 7.00 am to 12.00 and 12.00 to 19.00. All cases of PJI occurred in patients in the first group (7.00-12.00). There were no statistically significant differences in any of those groups, in disagreement with a previously study[12] (Table 1).

DISCUSSION

One of the most difficult and important targets in surgery is to avoid or early diagnose a PJI. Although the incidence of PJI is very low (0.69%) in our department, with an average follow-up of 595 d, this infection poses a serious threat due to the difficulties of treatment and the lower functional outcomes after healing[1]. We did not find any class with an evident major risk of PJI. In our study, we did not find any border value to predict PJI and all patients had similar parameters in both groups (non-PJI and PJI), in contrast to a previous study[14]. For some categories, such as sex, we observed a higher frequency of PJI in females than in males, but this difference was not statistically significant. Other authors have reported a higher incidence in males[12,15]. We did not find other studies with the control of blood values preoperatively and postoperatively in relation to the likelihood of PJI. Due to the lack of a sufficient number of patients, especially in the PJI group, we could not demonstrate a statistically significant difference between non-PJI patients and PJI ones. Maybe PJI has a multifactorial etiology[16] and our few cases of PJI could not demonstrate a higher incidence despite the reports in other studies[9,14,17,18]. Furthermore, we were unable to analyze other data such as urinary screening[19], which may also play a role in the prediction of a PJI, even though some authors have expressed doubts[20,21]. Some studies[20,21] have emphasized the increasing baseline risk of PJI with the increasing number of comorbidities. Another limit of this study was the inability to grade the severity of comorbidities. Many studies have reported different prognoses for different types and degrees of preexisting diseases[22]. All of these detailed analyses could not be carried out in our study, which is a limitation. The percentage of PJI was very low in our patients, and worldwide its incidence is decreasing due to surgical and drug management. Nonetheless, preoperative and postoperative THR surveillance needs to be more accurate in the future[23].

CONCLUSION

From the experience of all operations for THR performed at our department in the year 2016 we did not find any data that could help us avoid, predict, or early diagnose a PJI. This disagrees with other studies [14,16] and many accepted and undiscussed scientific convictions. The difference between our study and others may have been due to the low number of cases, especially in the PJI group (only 4 cases).

ARTICLE HIGHLIGHTS

Research background

Periprosthetic joint infection (PJI) in primary total hip replacement (THR) is one of the most important challenges in orthopedic surgery, so one important surgeon's goal is to avoid or diagnose a PJI early.

Research motivation

The incidence of PJI is very low (0.69%) in our department, with an average follow-up of 595 d. This infection poses a serious threat due to the difficulties of treatment and the lower functional outcomes after healing.

Research objectives

We tried to identify predictive signs of potential infection with the goal of exploring methodological approaches that could better inform daily orthopedic practice.

Research methods

We counted 583 THR for 578 patients and observed only 4 cases of infection (0.69%) with a mean follow-up of 596 d (min 30 max 1451). We reviewed duration and time of the surgery, presence, type and duration of the antibiotic therapy, preoperative diagnosis, blood values before and after surgery, transfusions, presence of preoperative drugs, and presence of some comorbidities to look for statistically significant differences between the patients that did and did not develop a PJI.

Research results

No preoperative, intraoperative, or postoperative analysis showed a higher incidence of PJI. We did not find any class with evident major risk of PJI. Some categories, such as female patients, showed a higher frequency of PJI, but this difference related to sex was not statistically significant.

Research conclusions

We did not find any category with a higher risk of PJI in THR, probably due to the lack of few cases of infection.

Research perspectives

PJI is an important topic and more research about the subject is needed. Probably due to the low number of cases, especially in the PJI group (4 cases), we did not attain the results we were expecting. Future studies are needed to add new information to the scientific literature, for example, data spanning 5 years or combined from multiple centers.

FOOTNOTES

Author contributions: Tella GF, Donadono C, Castagnini F, Bordini B, Cosentino M, Di Liddo M, and Traina F contributed equally to all aspects of this work.

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Data sharing statement: Technical appendix, statistical code, and dataset available from the corresponding author at c.donadono@gmail.com. Consent was not supposed to be obtained because of the characteristics of the study and the impossibility to contact the patient but by the way the presented data are anonymized and risk of identification is low.

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Country/Territory of origin: Italy

ORCID number: Giuseppe Ferdinando Tella 0000-0003-3605-4492; Cesare Donadono 0000-0003-3873-6016; Francesco Castagnini 0000-0002-3567-9194; Barbara Bordini 0000-0002-6606-4950; Monica Cosentino 0000-0001-5508-9776; Michele Di Liddo 0000-0002-9386-884X; Francesco Traina 0000-0002-0196-101X.

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ORIGINAL ARTICLE

Retrospective Cohort Study

Adjunctive platelet-rich plasma and hyaluronic acid injection after arthroscopic debridement in Kellgren-Lawrence grade 3 and 4 knee osteoarthritis

Henry Tirtosuharto, I Gede Eka Wiratnaya, Putu Astawa

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Henry Tirtosuharto, I Gede Eka Wiratnaya, Putu Astawa, Department of Orthopaedic and Traumatology, Faculty of Medicine Udayana University/Sanglah Hospital, Denpasar 80113, Bali, Indonesia

Corresponding author: I Gede Eka Wiratnaya, Doctor, Consultant Physician-Scientist, Department of Orthopaedic and Traumatology, Faculty of Medicine Udayana University/ Sanglah Hospital, Jalan Diponegoro, Dauh Puri Klod, Denpasar 80113, Bali, Indonesia. igewiratnaya@gmail.com

Abstract

BACKGROUND

Osteoarthritis (OA) is the most common cause of pain and disability, predominantly affecting the knee. The current management of knee OA falls short of completely stopping disease progression, particularly in Kellgren-Lawrence (KL) grade 3 and 4 knee OA. As such, joint replacement is often recommended, although only 15%-33% of candidates accept it. Alternative therapeutic options are still needed to prevent the progression of joint damage and delay the need for knee arthroplasty.

AIM

To investigate the effect of adjunctive platelet rich plasma (PRP) and hyaluronic acid (HA) after arthroscopic debridement in KL grade 3 and 4 knee OA.

METHODS

This retrospective cohort study used the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score and WOMAC sub-scores (pain, stiffness, and function) to assess 21 patients, grouped according to medical record data of treatment received: Arthroscopic debridement (n = 7); arthroscopic debridement with PRP (n = 7); or arthroscopic debridement with HA (n = 7). WOMAC scores and sub-scores at baseline and at 3 mo and 5 mo posttreatment were recorded. The three-group data were statistically analyzed using the tests of paired t, one-way analysis of variance, and post hoc least significant difference.

RESULTS

All three treatment groups showed significant improvements in WOMAC score and sub-scores from before treatment to 3 mo and 5 mo after treatment. However, the arthroscopic debridement with PRP treatment group, in particular, showed a significantly lower WOMAC pain score than the group who received arthroscopic debridement alone at 5 mo after the procedure (P = 0.03).

CONCLUSION

Compared to arthroscopic debridement alone, adjunctive PRP after arthroscopic debridement significantly lessened the patients' pain symptom.

Key Words: Arthroscopic debridement; Hyaluronic acid; Osteoarthritis; Platelet-rich plasma; Western Ontario and McMaster Universities Osteoarthritis Index; WOMAC score

Core Tip: This manuscript highlights the alternative approaches in managing knee osteoarthritis of Kellgren-Lawrence grade 3 and 4. Outcomes of arthroscopic debridement, arthroscopic debridement with platelet-rich plasma (PRP), or arthroscopic debridement with hyaluronic acid were evaluated prior to treatment and at 3 mo and 5 mo after the procedure. According to the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score and sub-scores (pain, stiffness, function), arthroscopic debridement with PRP provided significantly lower pain than arthroscopic debridement after treatment, however neither treatment was superior in the ability to improve total WOMAC score.

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INTRODUCTION

Osteoarthritis (OA) is the leading cause of pain and disability, with a 10-fold increased incidence and prevalence occurring in 30-years-old to 65-years-old age range[1-3]. In Indonesia, the prevalence of knee OA is appreciable, at 15.5% for men and 12.7% for women, with rates following the trend of increase with increased age[4].

To date, the management of knee OA is only capable of addressing symptomatic features and has been ineffective in halting progression of the disease itself. In the advanced stage of knee OA, joint replacement is the recommended management; since only 15%-33% of knee arthroplasty candidates are willing to submit themselves to the extensive surgery and recovery, an alternative treatment option is needed[5-8]. The proposed treatment involves adjunctive administration of platelet rich plasma (PRP) or hyaluronic acid (HA) following the knee arthroscopy. PRP is the blood's plasma component that has been prepared with a high concentration of platelets, which express the cytokines and growth factors to stimulate cartilage repair and inflammation decrease[6,7,9]. In knee OA, PRP has been shown to improve both the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score and the 36-item Short Form survey (commonly known as the SF-36) score[10,11]. Intraarticular HA injection has shown the benefits of chondroprotective effect, pain decrease, inflammatory response modulation and endogenous HA synthesis increase, and its wide application has demonstrated success in decreasing knee OA symptoms[12-15].

In this study, we aimed to investigate whether adjunctive treatment with PRP or HA after arthroscopic debridement was able to provide better outcomes then arthroscopic debridement alone.

MATERIALS AND METHODS

This was a retrospective cohort study based on medical record data. All treatments were performed by a single orthopedic surgeon in Denpasar, Bali, Indonesia between January 2021 and December 2021. Data were collected at Sanglah General Hospital and Surya Husada Ubung Hospital (Denpasar, Bali, Indonesia). The study sample was made up of KL grade 3 and 4 knee OA patients who had undergone arthroscopic debridement, arthroscopic debridement with PRP, or arthroscopic debridement with HA. The inclusion criteria were KL grade 3 and 4 knee OA patients, with diagnosis based on American College of Rheumatology Clinical and Radiological Classification Criteria, of ages 40-years-old to 70-

years-old, and who had failed conservative treatment. Patients with knee deformity due to trauma or congenital knee deformity were excluded. The study sample size was calculated according to a false positive rate of 5% (α = 0.5) and 80% power (β = 0.2), and on a predicted difference 56.87 point on mean WOMAC score changes (standard deviation 37.26)[16]. Accordingly, for multiple-group comparison, a minimum of 6 patients per group were determined to be required, and we included 7 patients per group.

The total 21 patients (*n* = 7 per three treatment groups) underwent the standard arthroscopic debridement procedure under general anesthesia. As a minimally invasive procedure, arthroscopic debridement is performed by inserting arthroscopes through small incisions, followed by debridement and irrigation. Debridement of necrotic chondral tissue is carried out to remove it from the cartilage, with subsequent saline-solution washing by irrigation[17]. For our patients, either PRP or HA was administered at 1 wk postsurgically *via* intraarticular injection to the patelofemoral joint under aseptic conditions. The HA treatment consisted of 3 mL Hyajoint-plus® (Macopharma, Tourcoing, France) at 20 mg/mL, while the PRP preparation protocol consisted of RegenKit® (Regen Lab, New York, NY, United States) administered as 5 mL. Any meniscus tear found during surgery was recorded and noted for its potential to serve as a confounding factor. There were no adverse reactions noted in the medical record data for any of the total 21 patients.

Outcomes

WOMAC score is an assessment instrument specific to OA that is widely used to evaluate symptom improvement in knee OA. WOMAC sub-scores consist of pain, stiffness, and functional assessments. Overall, the WOMAC and its sub-scores are reputed as reliable, valid, and responsive to change in patients with OA symptoms[18]. The highest total score is 96, with a lower score indicating improvement in knee OA symptoms.

We did not use magnetic resonance imaging (MRI) assessment as outcome measurement since this imaging modality was not in routine use in our hospitals during the study period.

Analysis

Data were analyzed using the Statistical Package for Social Sciences software (IBM Corp., Armonk, NY, United States). The Shapiro-Wilks normality test was performed. One-way analysis of variance was used to compare WOMAC scores among the three groups, and post hoc analysis was conducted using the least significant difference (commonly known as LSD) test. The paired *t*-test was used to compare baseline and follow-up WOMAC scores. $P < 0.05$ was considered statistically significant.

RESULTS

Subjects' characteristics

Among the 21 total patients included in the study, 61.9% were female and 38.1% were male. The mean age of the patients was 59.29 ± 6.61 years. Sixty-six percent of the patients had right knee OA and the remaining patients had left knee OA. None of the subjects had bilateral knee OA. Seventy-one percent of the patients had KL grade 3, and meniscus tear was found in 10 patients (47.6%) during surgery. The subjects' characteristics are summarized in Table 1.

WOMAC score and sub-scores

Before/after treatment comparisons showed that patients in all three groups had significantly lower WOMAC scores at 3 mo and 5 mo follow-up (Table 2). In the arthroscopic debridement group, a significant reduction was also found in pain score and physical function score at 3 mo follow-up (P = 0.002 and 0.011 respectively) and 5 mo follow-up (P = 0.000 and 0.001 respectively) but not in stiffness score, which was not significantly reduced at either the 3 mo or 5 mo follow-up (P = 0.091 and 0.067 respectively). In the arthroscopic debridement with HA group, a significant reductions was found in pain score and physical function score at 3 mo follow-up (P = 0.001 and 0.004 respectively) and 5 mo follow-up (P =0.001 and 0.000 respectively). In this group, the stiffness score was significantly reduced at the 5 mo follow-up (P = 0.026) but not at the 3 mo follow-up (P = 0.160). The arthroscopic debridement with PRP group showed a significant reduction in all WOMAC sub-scores at the 3 mo follow-up (P = 0.000, 0.019, and 0.001) and 5 mo follow-up (P = 0.000, 0.011, and 0.001 for pain, stiffness, and physical function scores respectively). Results from the paired *t*-test analyses are detailed in Table 2.

We also performed between-group comparisons for WOMAC score and sub-scores before treatment (at baseline) and after treatment (at the 3 mo and 5 mo follow-up); the findings are illustrated in Figure 1. At baseline, the mean WOMAC score was statistically similar among all groups (P = 0.65), with the arthroscopic debridement group having a mean ± SD score of 49.43 ± 10.33, the arthroscopic debridement with HA group having a mean ± SD score of 54.43 ± 14.55, and the arthroscopic debridement with PRP group having a mean ± SD score of 49.86 ± 7.22. No treatment was superior to another for WOMAC score at either the 3 mo follow-up or the 5 mo follow-up (P = 0.23 and 0.56

Table 1 Patient characteristics

Characteristic		Mean	Arthroscopic debridement	Arthroscopic debridement + HA	Arthroscopic debridement + PRP	*P* value
Patients		7	7	7	7	N/A
Age (yr)		59.29 ± 6.61	58.29 ± 6.75	57.29 ± 7.16	62.29 ± 5.71	0.34
Sex	Male	8 (38.1%)	3 (42.9%)	2 (28.6%)	3 (42.9%)	0.82
	Female	13 (61.9%)	4 (57.2%)	5 (71.4%)	4 (57.2%)	
Affected knee	Right	14 (66.7%)	5 (71.4%)	6 (85.7%)	3 (42.9%)	0.22
	Left	7 (33.3%)	2 (28.6%)	1 (14.3%)	4 (57.2%)	
KL grade	3	15 (71.4%)	7 (100%)	2 (28.6%)	6 (85.7%)	0.01
	4	6 (28.6%)	0	5 (71.4%)	1 (14.3%)	
Meniscus tear	Yes	10 (47.6%)	2 (28.6%)	5 (71.4%)	3 (42.9%)	0.25
	No	11 (52.4%)	5 (71.4%)	2 (28.6%)	4 (57.1%)	

Data are presented as *n* (%) or mean ± SD. HA: Hyaluronic acid; KL: Kellgren-Lawrence; N/A: Not applicable; PRP: Platelet-rich plasma.

Table 2 Paired *t*-test analysis of Western Ontario and McMaster Universities Osteoarthritis Index scores and sub-scores

Treatment	Outcome	Baseline	3 mo	5 mo	Paired *t*-test			
					Baseline *vs* 3 mo		Baseline *vs* 5 mo	
					t value	*P* value	*t* value	*P* value
Arthroscopic debridement	WOMAC score	49.43 ± 10.33	28.57 ± 9.09	18.57 ± 7.12	5.143	0.002	8.712	0.000
	Pain score	12.43 ± 2.76	6.00 ± 2.65	4.14 ± 3.02	5.391	0.002	17.488	0.000
	Stiffness score	4.57 ± 2.15	3.00 ± 0.82	2.14 ± 2.12	2.008	0.091	2.232	0.067
	Function score	32.43 ± 8.89	19.57 ± 7.30	12.29 ± 3.64	3.658	0.011	6.134	0.001
Arthroscopic debridement + HA	WOMAC score	54.43 ± 14.55	24.86 ± 12.09	14.86 ± 5.58	4.975	0.003	7.254	0.000
	Pain score	12.57 ± 4.50	4.43 ± 2.44	2.14 ± 0.70	5.943	0.001	6.177	0.001
	Stiffness score	4.57 ± 2.82	2.43 ± 1.62	0.86 ± 1.21	1.605	0.160	2.931	0.026
	Function score	37.29 ± 9.66	18.00 ± 8.87	11.86 ± 4.22	4.559	0.004	7.0029	0.000
Arthroscopic debridement + PRP	WOMAC score	49.86 ± 7.22	19.71 ± 5.74	15.00 ± 8.45	7.827	0.000	8.105	0.000
	Pain score	13.14 ± 2.34	4.14 ± 1.86	1.71 ± 0.95	7.937	0.000	12.060	0.000
	Stiffness score	5.43 ± 3.16	1.71 ± 1.38	0.86 ± 1.07	3.176	0.019	3.600	0.011
	Function score	31.29 ± 6.26	13.86 ± 4.10	12.43 ± 6.80	6.397	0.001	5.781	0.001

HA: Hyaluronic acid; PRP: Platelet-rich plasma; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.

respectively); the same was seen for the WOMAC sub-scores (Table 3). Upon post hoc analysis using the LSD test, pain score at the 5 mo follow-up was found to be significantly lower in the arthroscopic debridement with PRP group compared to the arthroscopic debridement group (*P* = 0.03) (Table 3).

DISCUSSION

OA was once considered a degenerative or “wear-and-tear” joint disease. However, it is now known to be a result of multifactorial interplay among mechanical factors, joint integrity, local inflammation, cellular, and biochemical processes[19]. To the best of our knowledge, our retrospective cohort study presented herein is the first to compare WOMAC score and WOMAC sub-score parameters between arthroscopic debridement treatments, alone and with postsurgical adjunctive PRP or HA, in KL grade 3

Table 3 Analysis of variance and least significance difference post hoc test for Western Ontario and McMaster Universities Osteoarthritis Index score and sub-scores

Score	Period	Arthroscopic debridement	Arthroscopic debridement + HA	Arthroscopic debridement + PRP	ANOVA *P* value	LSD post hoc test; *P* value		
						I *vs* II	I *vs* III	II *vs* III
WOMAC score	Baseline	49.43 ± 10.33	54.43 ± 14.55	49.86 ± 7.22	0.65	0.41	0.94	0.45
	3 mo	28.57 ± 9.09	24.86 ± 12.09	19.71 ± 5.74	0.23	0.47	0.09	0.32
	5 mo	18.57 ± 7.12	14.86 ± 5.58	15.00 ± 8.45	0.56	0.34	0.36	0.97
Pain score	Baseline	12.43 ± 2.76	12.57 ± 4.50	13.14 ± 2.34	0.91	0.94	0.69	0.75
	3 mo	6.00 ± 2.65	4.43 ± 2.44	4.14 ± 1.86	0.30	0.23	0.16	0.82
	5 mo	4.14 ± 3.02	2.14 ± 0.70	1.71 ± 0.95	0.06	0.06	0.03	0.67
Stiffness score	Baseline	4.57 ± 2.15	4.57 ± 2.82	5.43 ± 3.16	0.80	1.00	0.57	0.57
	3 mo	3.00 ± 0.82	2.43 ± 1.62	1.71 ± 1.38	0.22	0.43	0.08	0.32
	5 mo	2.14 ± 2.12	0.86 ± 1.21	0.86 ± 1.07	0.22	0.14	0.14	1.00
Function score	Baseline	32.43 ± 8.89	37.29 ± 9.66	31.29 ± 6.26	0.39	0.29	0.80	0.20
	3 mo	19.57 ± 7.30	18.00 ± 8.87	13.86 ± 4.10	0.32	0.68	0.15	0.29
	5 mo	12.29 ± 3.64	11.86 ± 4.22	12.43 ± 6.80	0.98	0.83	0.96	0.84

HA: Hyaluronic acid; PRP: Platelet-rich plasma; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index. I: Arthroscopic debridement; II: Arthroscopic debridement + HA; III: Arthroscopic debridement + PRP.

and 4 knee OA patients.

Arthroscopic debridement in knee OA is carried out when conservative treatment does not give satisfactory improvement in clinical symptoms but when joint replacement is not yet indicated[17]. Arthroscopy removes cartilage degradation products, mechanical irritants, and inflammatory cells from the joints, thus reducing pain and improving knee symptoms in KL grade 3 and 4 knee OA patients[20,21]. According to Kirkley *et al*[20], arthroscopy is able to delay total knee replacement in KL grade 3 knee OA patients aged ≥ 55 years. Steadman *et al*[22] further pinpointed that it was able to delay total knee replacement for 6.8 years. Despite the beneficial outcome, the use of arthroscopy in knee OA has remained controversial, with some studies reporting no significant difference being achieved through placebo arthroscopy, physical therapy, or medication[20,23]. However, adjunctive treatment with intraarticular HA or PRP injection after arthroscopic debridement has been expected to give better outcome than arthroscopic debridement alone.

Application of exogenous HA increases lubrication and reduces friction at the joint surface, thereby preventing chondrocyte degradation[13]. It also stimulates endogenous HA production[12] and produces anti-inflammatory effects by inhibiting tumor necrosis factor-alpha, interleukin (IL)-1 beta, and IL-8 expression[13]. The analgetic effects of HA treatment occur by its prompting a decrease in stress-activated ion channel sensitivity[12].

PRP is a small amount of plasma with concentrated platelets, giving it appreciable therapeutic anti-inflammatory, analgetic, and tissue regeneration properties. The anti-inflammatory effects occur through inhibition of the nuclear factor-kappa B (NF-κB) pathway and matrix metalloproteinases (MMPs)[24-27]. Upon application to the human system, it releases protease-activated receptor 4 peptide and anabolic chondral factors to provide analgetic effects[27,28]. PRP therapy also works in cartilage by releasing growth factors (specifically, platelet-derived growth factor and vascular endothelial growth factor, among various other growth factors), which are able to increase endogenous HA synthesis, re-epithelization, and tissue repair[29-32].

Our study showed significant reductions in WOMAC score and the sub-scores of pain and function for patients in the arthroscopic debridement group at their 3 mo and 5 mo follow-ups. These findings are in line with those from a study by Su *et al*[9], who showed that patients with KL grade 3 and 4 knee OA had significantly reduced WOMAC score at 1 year and 2 years after arthroscopic debridement, compared to conservative treatment. In another study, Bohnsack *et al*[21] performed arthroscopy in KL grade 3 and 4 knee OA patients and showed that Lysholm score (an 8-item knee scoring scale) was significantly improved, resulting in the improved ability to perform daily activities. In contrast, a study from Kirkley *et al*[20] showed that patients with KL grade 2-4 knee OA who underwent arthroscopic debridement and lavage experienced no significant improvement in WOMAC and SF-36 scores, compared to patients who received conservative treatment. Similarly, another study by Moseley *et al*[23] that compared arthroscopic debridement and placebo surgery (skin incision only) in knee OA patients

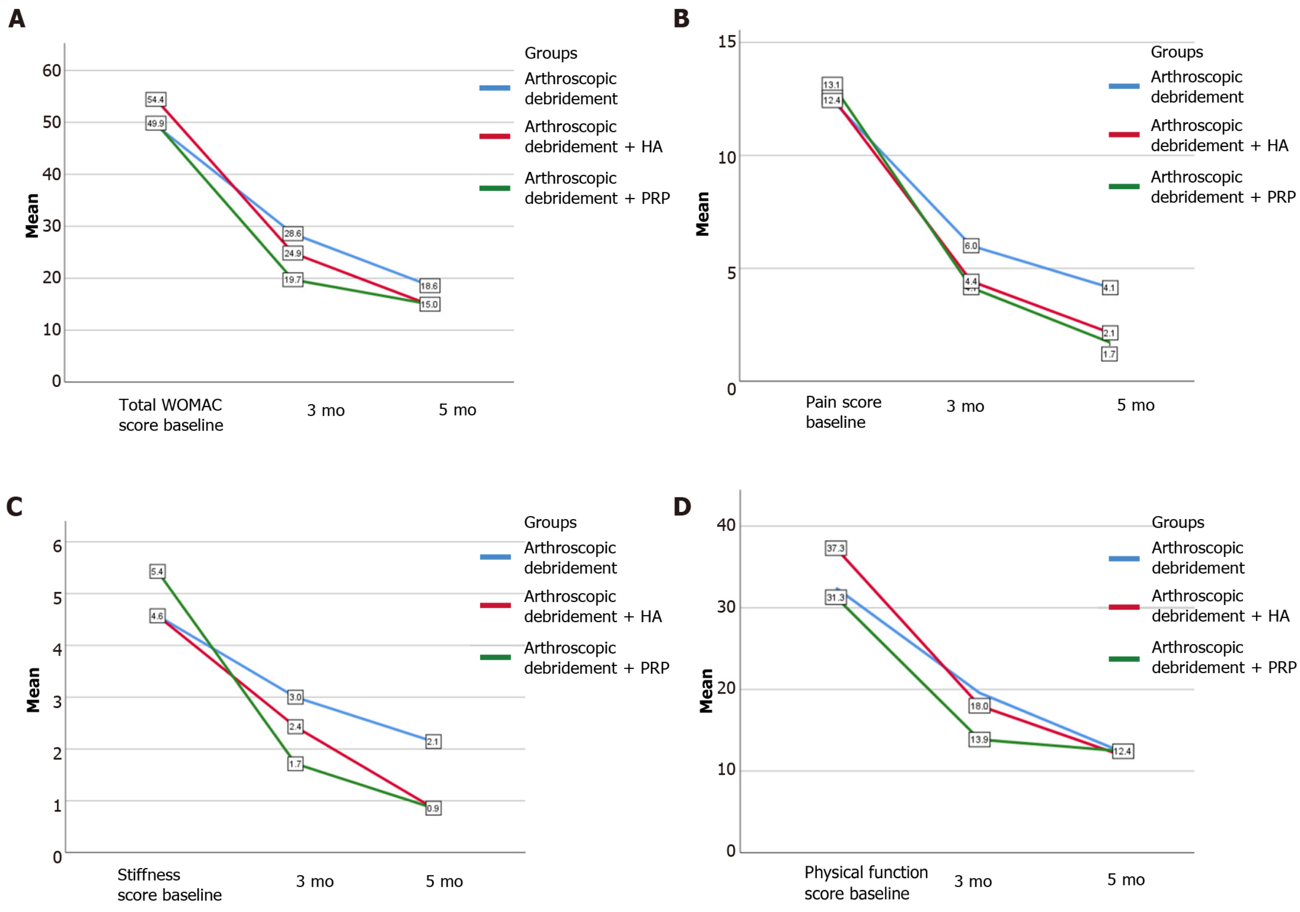

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Figure 1 Mean outcome scores at baseline and at 3 mo and 5 mo follow-ups. A: Mean Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score; B: Mean pain score; C: Mean stiffness score; D: Mean physical function score. WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; HA: Hyaluronic acid; PRP: Platelet rich plasma.

yielded no significant difference in the groups' SF-36 and pain scale scores. Our study also showed that stiffness score did not significantly decrease in the arthroscopic debridement group. This could be due to the concept that application of the irrigation solution during arthroscopic debridement was not only meant to remove detritus but also synovial fluid and the HA-layer covering the cartilage; in this way, the shock absorbent layer and lubricating function would be affected[17].

We expected adjunctive treatment with HA intraarticular injection after arthroscopic debridement to overcome the limitation described directly above. And, indeed this was the case; our HA-treated arthroscopic debridement patients experienced significant improvement not only in WOMAC score, pain score, and function score at the 3 mo and 5 mo follow-ups but also in the stiffness score at the 5 mo follow-up. Similar improvements were shown in a study by Hempfling[17], which had compared knee arthroscopy with and without postprocedure HA injection. In that study, at the 12 mo follow-up, arthroscopy with HA was superior in clinical global impression, improved restricted ability to walk 100 m, pain on walking, and night pain. Atay *et al*[33] evaluated HA injections after arthroscopic debridement surgery in KL grade 2-3 knee OA and at 12 mo follow-up; there was a significant difference found in WOMAC score changes between the arthroscopy with HA group and the arthroscopy without HA group. Finally, a more recent meta-analysis by Shen *et al*[34] showed that HA after arthroscopy was able to reduce pain on motion, indicating that HA is significantly associated with increased physical function and WOMAC score.

Our search of the literature found no previous study on PRP injection following arthroscopic debridement in knee OA patients. In our study, this adjunctive treatment resulted in significantly lower WOMAC score and all WOMAC sub-scores at 3 mo and 5 mo follow-ups compared to baseline. Raeissadat *et al*[35] had evaluated WOMAC score in knee OA patients who received PRP injection; at the 6 mo follow-up, they found a significant improvement in WOMAC score and SF-36, compared to baseline. Another study by Patel *et al*[11] compared WOMAC score in knee OA patients who received one PRP injection, two PRP injections, or normal saline injection; a significant improvement in all WOMAC parameters occurred within 2 wk to 3 wk and lasted for 6 mo, whereas in the normal saline group, the WOMAC score worsened.

In our study, we compared WOMAC score and sub-scores between three treatment groups and there was no superiority between the groups. A pilot study by Trueba Vasavilbaso *et al*[16] comparing arthroscopic debridement, arthroscopic debridement with HA and arthroscopic debridement with PRP has shown that even though WOMAC score was significantly decreased at the 3 mo follow-up (*vs* baseline scores) in all groups, there was no significant difference in WOMAC score among them. A significant difference in WOMAC score was found at the 12 mo and 18 mo follow-ups, particularly between the group treated by arthroscopy alone and the group treated with arthroscopy and three HA injections. It is important to note that our relatively short follow-up time may have contributed to the non-significant differences in WOMAC score among the groups.

Post hoc analysis in our study showed a significant difference between the arthroscopic debridement and arthroscopic debridement with PRP groups in pain score at the 5 mo follow-up. This significant difference could have been due to the ability of PRP to inhibit pathways contributing to joint pain *via* its anti-inflammatory properties through inhibition of the NF-κB pathway and MMPs, decreasing IL-6 production, and releasing IL-10 anti-inflammatory cytokines[24-26].

According to Rajpoot *et al*[36], KL grade is positively correlated with WOMAC score, but to the best of our knowledge there has been no study specifically comparing WOMAC score in KL grade 3 and 4. In our study, the number of patients with KL grade 3 knees OA was significantly higher than those with KL grade 4, but we found no statistically significant difference either in WOMAC score or WOMAC sub-scores at baseline.

Lesions in knee OA not only affect the cartilage but also other structures, including the meniscus. A meniscal tear can contribute to progression of knee OA by its negative effects on load distribution, shock absorption, and stability of the knee joint. Individuals with meniscal tear frequently present with knee OA, which contributes to symptoms of the former. Reportedly, among KL grade 2-4 knee OA patients, 63% have meniscal tear[37,38]. Forty-seven percent of the patients in our study had meniscal tear discovered during the surgery. Even though a meniscal tear can contribute to knee OA symptoms, the occurrence of such was comparable at baseline in our patients, thus we did not do further statistical analysis or adjustment.

Limitations

The main limitation of this study was the small number of participants, as only 21 patients were enrolled. The short follow-up period precluded our ability to evaluate long-term outcomes of the three treatment groups. We suggest a prospective cohort and a longer follow-up period for future research and including imaging evaluation, such as with MRI.

CONCLUSION

Adjunctive PRP after arthroscopic debridement gave better improvement in pain symptom compared to arthroscopic debridement alone. However, neither treatment was superior regarding the ability to improve WOMAC score and other knee OA symptoms.

ARTICLE HIGHLIGHTS

Research background

The current management for knee osteoarthritis (OA) is not able to stop disease progression, particularly in Kellgren-Lawrence (KL) grade 3 and 4 OA. Thus, alternative therapeutic options are needed to prevent the progression of joint damage in OA and delay the need for knee arthroplasty.

Research motivation

Alternative therapies for knee OA are needed that can prevent disease progression. Such treatment is expected to increase quality of life and prevent or delay the need for arthroplasty.

Research objectives

To investigate whether adjunctive treatment with platelet-rich plasma (PRP) and hyaluronic acid (HA) after arthroscopic debridement provides better outcomes then arthroscopic debridement alone.

Research methods

This was a retrospective cohort study using medical record data. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score and its sub-scores was used as the outcome parameter. The data were analyzed using the paired *t*-test, one-way analysis of variance, and post hoc least significant difference test.

Research results

Adjunctive PRP or HA after arthroscopic debridement was not superior to arthroscopic debridement alone in improving knee OA symptoms. However, adjunctive PRP resulted in improvement of pain symptoms. A longer evaluation period is needed to assess the long-term outcome.

Research conclusions

Adjunctive PRP or HA after arthroscopic debridement was not superior to arthroscopic debridement alone in improving knee OA symptoms. Adjunctive PRP after arthroscopic debridement was more beneficial in reducing pain.

Research perspectives

The results of this study are expected to provide clinicians with an alternative treatment for KL grade 3 and 4 knee OA. Future research with a prospective cohort and longer follow-up period is needed.

FOOTNOTES

Author contributions: Tirtosuharto H designed and conceived the study, collected the data, conducted the data analyses, and drafted the manuscript; Wiratnaya IGE and Astawa P designed and conceived the study, and revised the manuscript.

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Country/Territory of origin: Indonesia

ORCID number: Henry Tirtosuharto 0000-0001-8480-4185; I Gede Eka Wiratnaya 0000-0003-0126-7463; Putu Astawa 0000-0003-4194-8343.

Corresponding Author's Membership in Professional Societies: Ikatan Dokter Indonesia, No. 119318.

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ORIGINAL ARTICLE

Retrospective Study

Utilising the impact of COVID-19 on trauma throughput to adapt elective care models for more efficient trauma care

Kunal Kulkarni, Rohi Shah, Jitendra Mangwani, Aamer Ullah, Omar Gabbar, Elaine James, Joseph Dias

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Kunal Kulkarni, Rohi Shah, Jitendra Mangwani, Aamer Ullah, Omar Gabbar, Elaine James, Joseph Dias, Department of Trauma & Orthopaedics, University Hospitals of Leicester NHS Trust, Leicester General Hospital, Leicester LE5 4PW, United Kingdom

Corresponding author: Kunal Kulkarni, BMBCh, MA (Oxon), MSc, FRCS (Tr&Orth), European Board of Hand Surgery Diploma, Consultant Trauma & Orthopaedic Surgeon, Department of Trauma & Orthopaedics, University Hospitals of Leicester NHS Trust, Leicester General Hospital, Gwendolen Road, Leicester LE5 4PW, United Kingdom. kunalkulkarni@doctors.org.uk

Abstract

BACKGROUND

Coronavirus disease 2019 (COVID-19) has necessitated adaptations in local trauma services, with implementation of novel methods of practice, strategic adaptations, and shifting of resource management. Many of these may serve the driver for landmark changes to future healthcare provision.

AIM

To analyse the impact of COVID-19 on service provision by comparing throughput and productivity metrics with preceding years to identify differences in practice that were successful, cost-effective, and sustainable.

METHODS

We quantified orthopaedic trauma care provision at a single University Teaching Hospital over a three consecutive year period, from 1st January 2018 to 31st December 2020. Each year was split into four phases based on the 2020 national COVID-19 pandemic periods. We quantitatively analysed change in rates of inpatient trauma operative case load, sub-specialty variation, theatre throughput, and changes in management strategy. Qualitative analysis was based on multidisciplinary team interviews to highlight changes to care pathways.

RESULTS

Of 1704 cases were admitted in 2020, 11.9% and 12.4% fewer than 2019 and 2018, respectively. During phase 1, hip fractures encompassed the majority (48.8%) of trauma throughput, with all other subspecialties seeing a reduction. Mean length of stay was shorter during phase 1 (5.7 d); however, the time in theatre was longer (144.3 min). Both, Charlson (0.90) and Elixhauser (1.55) Comorbidity Indices indicated the most co-morbid admissions during 2020 phase 1.

CONCLUSION
COVID-19 has resulted in a paradigm shift in how care is accessed and delivered, with many evolving changes and adaptations likely to leave an impression upon healthcare provision in the future.

Key Words: COVID-19; Trauma; Surgery; Throughput; Care provision

Core Tip: Based on our findings, we have made several recommendations that we will adopt locally going forward. We encourage other teams facing similar challenges to consider these factors to improve the care of trauma patients: (1) Dynamic elective approaches to care can reduce length of stay (LOS): The 'elective mindset' of the elective hospital nursing/physical therapy/occupational therapy teams yielded more expeditious post-operative rehabilitation our trauma patients, ensuring faster optimisation of a more co-morbid cohort of patients and reduced LOS; (2) Sustain the rising trend in safe non-operative management to reduce inpatient workload: This was a trend particularly observed in hand and wrist/foot and ankle trauma where the care pathways were altered in the face of rising coronavirus disease 2019 cases; and (3) Maintaining rapid re-education of skills: By rapidly adopting locally-relevant versions of national guidance and developing standardised algorithms and training pathways.

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INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has significantly impacted the provision of healthcare globally. Not only were elective planned care services largely paused, but ongoing essential services, such as trauma, had to adapt their ways of working to maintain safety for patients and healthcare professionals[1].

With the National Health Service (NHS) slow to effect change, these COVID-19 necessitated adaptations may serve the driver for landmark changes to the way healthcare is provided[2]. Should these changes prove successful, they may yield more sustained differences to the way we deliver care in the future. Hospitals across the United Kingdom have implemented strategic changes, with shifting of resource management and implementation of novel methods of practice (such as virtual consultations) [3-5]. These provided the ideal opportunity to drive much needed technological upgrades into the healthcare ecosystem. The post-pandemic environment is full of opportunities to improve the flexibility of care provision for the benefit of both, patients and providers, with the ultimate aim of creating enhanced and self-sustaining care models.

With this in mind, we sought to gain an in-depth view of the impact of COVID-19 on our local trauma service provision, by comparing our trauma throughput and other key productivity metrics with the preceding years to identify any key differences and adaptations that had occurred within the department to sustain clinical practice. By evaluating changes to practices implemented due to COVID-19 at our trauma unit, our goal was to evaluate those changes that were successful, cost-effective, easily adapted by clinicians, and deemed sustainable for the future, with a view to sharing our learnings more widely.

MATERIALS AND METHODS

Aims

We performed a comprehensive retrospective analysis of the objective impact of COVID-19 on our local trauma service provision, by comparing 2020 metrics with the equivalent 12-mo time periods in both 2019 and 2018. This study was formally registered and approved by our (KK1) Clinical Audit and Quality Improvement Team. The specific aspects of care provision we sought to evaluate included: (1) Change in rates of inpatient trauma case load; (2) Sub-specialty variation in trauma case load; (3) Theatre throughput (numbers of cases, duration, turnaround time); (4) Changes in trends in trauma management (particularly rates of non-operative interventions); and (5) Changes to local strategy to care delivery.

Scope, population, timeline

Comparison of all trauma clinical activity at the Orthopaedic Trauma Unit of a single United Kingdom University Teaching Hospital over a three consecutive year period, from 1st January 2018 to 31st December 2020 (*i.e.,* 2018, 2019, 2020). For the purpose of this evaluation, each year was split into four phases based upon the main national COVID-19 pandemic periods in 2021 (Table 1).

Data sources

Data was obtained using the Hospital Information Support System (HISS) specifically coded for Trauma and Orthopaedics (HISS code 10). This data included information on patient co-morbidities [converted to Charlson Comorbidity Index (CCI)], patient demographic and mortality data. Operative data and timings were obtained using our Operating Theatre Software (ORMIS, code 10) and cross-referenced with a manually maintained Microsoft Excel (v16.46) encrypted spreadsheet of cases booked for theatre by our Trauma Coordinators. Descriptions of changes to patient care pathways were obtained through interviews of the multidisciplinary team (MDT), including senior management, Orthopaedic and Orthogeriatric clinicians, and ward teams (nursing and therapy).

Primary outcomes

Rates of all trauma caseload management across the three years, including a breakdown of: (1) Variation in total trauma throughput each year by phase; (2) Variation in specific subspecialty trauma by phase (subspecialties included: Hip, knee, foot and ankle, hand & wrist, shoulder, elbow, and complex multi-site); (3) CCI, Elixhauser Comorbidity Sum Index (ECI); (4) Inpatient length of stay (LOS); and (4) For operated cases, the time interval & delay to treatment (*i.e.,* from admission time to surgery start time).

Analysis

Descriptive statistics were presented as means ± SD. Qualitative analysis of interviews was performed to group the key changes to care pathways. The quantitative data was then analysed in the context of changes to practice, with a view to identifying sustainable interventions to maintain going forward.

RESULTS

A total of 1704 trauma cases were admitted to our trauma unit in 2020. This was 11.9% fewer than in 2019 (1934 cases) and 12.4% fewer than in 2018 (1945 cases) (Table 2). Figure 1A highlights the variation in total trauma throughput by phase.

Variation in subspecialty trauma

Table 2 highlight the variation in subspecialty trauma for phases 0-3 for each year investigated. During the 2020 lockdown (phase 1), hip fractures remained the bulk (48.4%) of the surgical workload. This was a slightly higher proportion than in 2019 (41.6%), and 2018 (37.9%). Absolute numbers for hip trauma remained equivalent (146 procedures). Figure 1B highlights the variation in trauma load during the lockdown period. Conversely, we noted a reduction in foot and ankle procedures during phase 1 in 2020 (26 procedures; 8.7% of overall workload) compared to 2019 (47 procedures; 13.4% of overall workload) and 2018 (60 procedures; 17.3% of overall workload). Similar reductions were noted for hand and wrist trauma in 2020 (44 procedures; 14.7% of overall workload) compared to 2019 (54 procedures; 15.4% of overall workload) and 2018 (53 procedures; 15.3% of overall workload). In 2020, surgical throughput during lockdown phase 1 was lower by 52 procedures than 2019 and by 47 in comparison to 2018. Additionally, all subspecialties, except for hips (146 procedures in both 2020 and 2019) and elbows (21 procedures in 2020, 19 in 2019), saw a reduction in absolute procedural numbers in comparison to 2019.

Patient demographics, LOS, comorbidities, and theatre parameters

Tables 3-5 highlight the variation in patient demographic, LOS, comorbidity indices, and theatre parameters from 2018 to 2020. More detailed breakdown of variation is presented in Supplementary Tables 1-3. The mean LOS was significantly shorter during the 2020 phase 1 (lockdown phase) (5.7 d) compared to 2019 (7.5 d) and 2018 (6.8 d). CCI[6], which encompasses 19 medical conditions and is the most widely used comorbidity risk adjustment model for Orthopaedic surgery, showed a higher mean index during the 2020 lockdown (0.90) compared to 2019 (0.84) and 2018 (0.65). These findings were replicated using the ECI[7], which utilises 31 conditions, highlighting more co-morbid patients during phase 1 in 2020 [1.55 *vs* 1.36 (2019) *vs* 1.09 (2018)].

The 'hours to surgery' metric was calculated from the decision to admit the patient to hospital to the time to surgery. There was no significant variation between the three years for both phase 0 (30.7 h *vs* 32.0 h *vs* 29.2 h) and phase 1 (30.8 h *vs* 32.1 h *vs* 31.5 h). However, the actual time in theatre (en-

Table 1 Timelines for each phase evaluated

Phase	Description	Dates	Days
Phase 0	Pre-lockdown	1st January - 22nd March	81
Phase 1	Lockdown	23rd March - 31st May	70
Phase 2	Post-lockdown	1st June - 30st September	122
Phase 3	To year end	1st October - 31st December	92

Table 2 Subspecialty trauma breakdown (2018-2020)

Subspecialty	Year	Phase 0	Phase 1	Phase 2	Phase 3	Total
		Pre-lockdown	Lockdown	Post-lockdown	To year end	
Hip	2018	183 (39.8%)	131 (37.9%)	311 (37.0%)	118 (39.6%)	743 (38.2%)
	2019	172 (39.3%)	146 (41.6%)	339 (40.4%)	139 (45.4%)	796 (41.2%)
	2020	163 (41.3%)	146 (48.8%)	291 (36.6%)	76 (35.3%)	676 (39.7%)
Knee	2018	26 (5.7%)	14 (4.0%)	47 (5.6%)	16 (5.4%)	103 (5.3%)
	2019	37 (8.4%)	24 (6.8%)	53 (6.3%)	27 (8.8%)	141 (7.3%)
	2020	36 (9.1%)	16 (5.4%)	55 (6.9%)	7 (3.3%)	114 (6.7%)
Foot & ankle	2018	69 (15.0%)	60 (17.3%)	120 (14.3%)	45 (15.1%)	294 (15.1%)
	2019	65 (14.8%)	47 (13.4%)	102 (12.2%)	39 (12.7%)	253 (13.1%)
	2020	45 (11.4%)	26 (8.7%)	98 (12.3%)	36 (16.7%)	205 (12.0%)
Hand & wrist	2018	70 (15.2%)	53 (15.3%)	148 (17.6%)	51 (17.1%)	322 (16.6%)
	2019	58 (13.2%)	54 (15.4%)	149 (17.8%)	33 (10.8%)	294 (15.2%)
	2020	60 (15.2%)	44 (14.7%)	147 (18.5%)	42 (19.5%)	293 (17.2%)
Shoulder	2018	27 (5.9%)	25 (7.2%)	45 (5.4%)	20 (6.7%)	117 (6.0%)
	2019	30 (6.8%)	22 (6.3%)	47 (5.6%)	21 (6.9%)	120 (6.2%)
	2020	27 (6.8%)	13 (4.3%)	52 (6.5%)	21 (9.8%)	113 (6.6%)
Elbow	2018	32 (7.0%)	32 (9.2%)	87 (10.3%)	16 (5.4%)	167 (8.6%)
	2019	29 (6.6%)	19 (5.4%)	62 (7.4%)	12 (3.9%)	122 (6.3%)
	2020	24 (6.1%)	21 (7.0%)	75 (9.4%)	15 (7.0%)	135 (7.9%)
Complex multi-site	2018	16 (3.5%)	8 (2.3%)	16 (1.9%)	7 (2.3%)	47 (2.4%)
	2019	4 (0.9%)	7 (2.0%)	14 (1.7%)	7 (2.3%)	32 (1.7%)
	2020	4 (1.0%)	1 (0.3%)	9 (1.1%)	3 (1.4%)	17 (1.0%)
Polytrauma	2018	37 (8.0%)	23 (6.6%)	67 (8.0%)	25 (8.4%)	152 (7.8%)
	2019	43 (9.8%)	32 (9.1%)	73 (8.7%)	28 (9.2%)	176 (9.1%)
	2020	36 (9.1%)	32 (10.7%)	68 (8.6%)	15 (7.0%)	151 (8.9%)

compasses both anaesthetic and operative surgical time) was notably longer during the 2020 lockdown phase 1 (144.3 min *vs* 96.3 min *vs* 92.9 min). This increased time can be accounted for by the COVID-19 related measures that were introduced into theatre practice during phase 1 for infection prevention and control (including donning and doffing, cleaning, theatre air changes), requiring strict adherence and understandably taking notably longer than standard processes. Therefore, while overall throughput and number of cases per day was lower in the 2020 lockdown phase, the time in theatre per case was greater, and consequently, the overall hours to get to surgery remained unchanged. Following the lockdown and the anticipated normalization of hospital practices (phase 2), we noted a reduction in the 'hours to surgery' in comparison to 2019 and 2018 (24.5 h *vs* 29.2 h *vs* 34.7 h). This timing was almost 21% less than phase 1 and phase 0 of the same year, suggestive of more effective pre-operative patient optimisation, or surgery being performed largely on fitter patients who required less pre-operative work-up during that time of year [2020 CCI - 0.68 (phase 2) *vs* 0.90 (phase 1)], as reflected in the 2020

Table 3 Patient demographics, length of stay, comorbidity indices and theatre parameters for 2018

	Phase 0 (*n* = 709)	Phase 1 (*n* = 571)	Phase 2 (*n* = 1363)	Phase 3 (*n* = 486)	Total (*n* = 3129)
	mean ± SD				
Age at injury	61.23 ± 22.40	56.40 ± 24.04	57.52 ± 24.36	59.06 ± 23.79	58.39 ± 23.83
Length of spell (d)	8.39 ± 10.31	6.84 ± 8.57	6.76 ± 10.19	7.02 ± 9.45	7.18 ± 9.84
Charlson Comorbidity Index	0.72 ± 1.31	0.65 ± 1.24	0.68 ± 1.26	0.60 ± 1.21	0.67 ± 1.26
Elixhauser Comorbidity Index	1.19 ± 1.39	1.09 ± 1.36	1.14 ± 1.38	1.06 ± 1.31	1.13 ± 1.37
Hours to surgery	29.24 ± 50.75	31.46 ± 48.29	34.72 ± 91.27	26.22 ± 52.95	31.54 ± 71.10
Time in theatre	98.59 ± 58.34	92.86 ± 48.23	94.33 ± 46.30	95.49 ± 48.66	95.23 ± 50.04
Time in theatre/recovery	61.23 ± 22.40	56.40 ± 24.04	57.52 ± 24.36	59.06 ± 23.79	58.39 ± 23.83
Sex: Female	383 ± 54.0%	296 ± 51.8%	726 ± 53.3%	249 ± 51.2%	1654 ± 52.9%
Sex: Male	326 ± 46.0%	275 ± 48.2%	637 ± 46.7%	237 ± 48.8%	1475 ± 47.1%

Table 4 Patient demographics, length of stay, comorbidity indices and theatre parameters for 2019

	Phase 0 (*n* = 664)	Phase 1 (*n* = 563)	Phase 2 (*n* = 1315)	Phase 3 (*n* = 471)	Total (*n* = 3013)
	mean ± SD				
Age at injury	58.89 ± 24.03	60.66 ± 23.17	58.66 ± 23.95	61.11 ± 22.98	59.47 ± 23.68
Length of spell (d)	7.30 ± 8.05	7.50 ± 9.90	6.67 ± 8.60	8.01 ± 10.88	7.18 ± 9.14
Charlson Comorbidity Index	0.71 ± 1.28	0.84 ± 1.49	0.78 ± 1.35	0.77 ± 1.30	0.77 ± 1.35
Elixhauser Comorbidity Index	1.20 ± 1.38	1.36 ± 1.55	1.39 ± 1.53	1.34 ± 1.42	1.33 ± 1.49
Hours to surgery	32.02 ± 57.64	32.13 ± 51.56	29.17 ± 47.03	31.96 ± 56.83	30.79 ± 51.99
Time in theatre	101.03 ± 49.49	96.30 ± 67.04	94.85 ± 57.61	95.95 ± 47.63	96.64 ± 56.36
Time in theatre/recovery	213.08 ± 110.23	208.29 ± 115.17	214.99 ± 141.51	228.39 ± 146.20	215.56 ± 131.70
Sex: Female	332 ± 50.0%	291 ± 51.7%	675 ± 51.3%	239 ± 50.7%	1537 ± 51.0%
Sex: Male	332 ± 50.0%	272 ± 48.3%	640 ± 48.7%	232 ± 49.3%	1476 ± 49.0%

Table 5 Patient demographics, length of stay, comorbidity indices and theatre parameters for 2020

	Phase 0 (*n* = 640)	Phase 1 (*n* = 425)	Phase 2 (*n* = 1210)	Phase 3 (*n* = 413)	Total (*n* = 2688)
	mean ± SD				
Age at injury	59.46 ± 23.95	62.16 ± 23.61	57.70 ± 24.07	60.97 ± 23.47	59.33 ± 23.93
Length of spell (d)	7.05 ± 7.87	5.69 ± 5.90	5.71 ± 7.54	7.53 ± 8.86	6.30 ± 7.64
Charlson Comorbidity Index	0.77 ± 1.23	0.90 ± 1.45	0.68 ± 1.19	0.68 ± 1.25	0.73 ± 1.26
Elixhauser Comorbidity Index	1.27 ± 1.46	1.55 ± 1.63	1.21 ± 1.37	1.19 ± 1.39	1.28 ± 1.44
Hours to surgery	30.71 ± 49.37	30.84 ± 34.56	24.50 ± 37.98	24.59 ± 37.14	26.97 ± 40.41
Time in theatre	95.62 ± 50.10	144.25 ± 64.24	127.98 ± 54.37	123.20 ± 54.48	122.11 ± 57.35
Time in theatre/recovery	215.97 ± 124.31	175.22 ± 117.92	195.23 ± 106.09	203.28 ± 132.37	199.65 ± 117.42
Sex: Female	347 ± 54.2%	237 ± 55.8%	649 ± 53.6%	234 ± 56.7%	1467 ± 54.6%
Sex: Male	293 ± 45.8%	188 ± 44.2%	561 ± 46.4%	179 ± 43.3%	1221 ± 45.4%

EIC. However, the absolute number of trauma admissions was also lower in phase 2 of 2020 compared to the equivalent timeframes in 2019 and 2018 (1210 *vs* 1315 *vs* 1363), which would contribute to the observed decrease in hours to surgery. The actual 'time in theatre' remained high (128.0 min) in the 2020 phase 2, but some improvement was noted over phase 1 (144.3 min). While theatre practices became more streamlined and efficient, the core aspects of COVID-19 measures remained vastly unchanged,

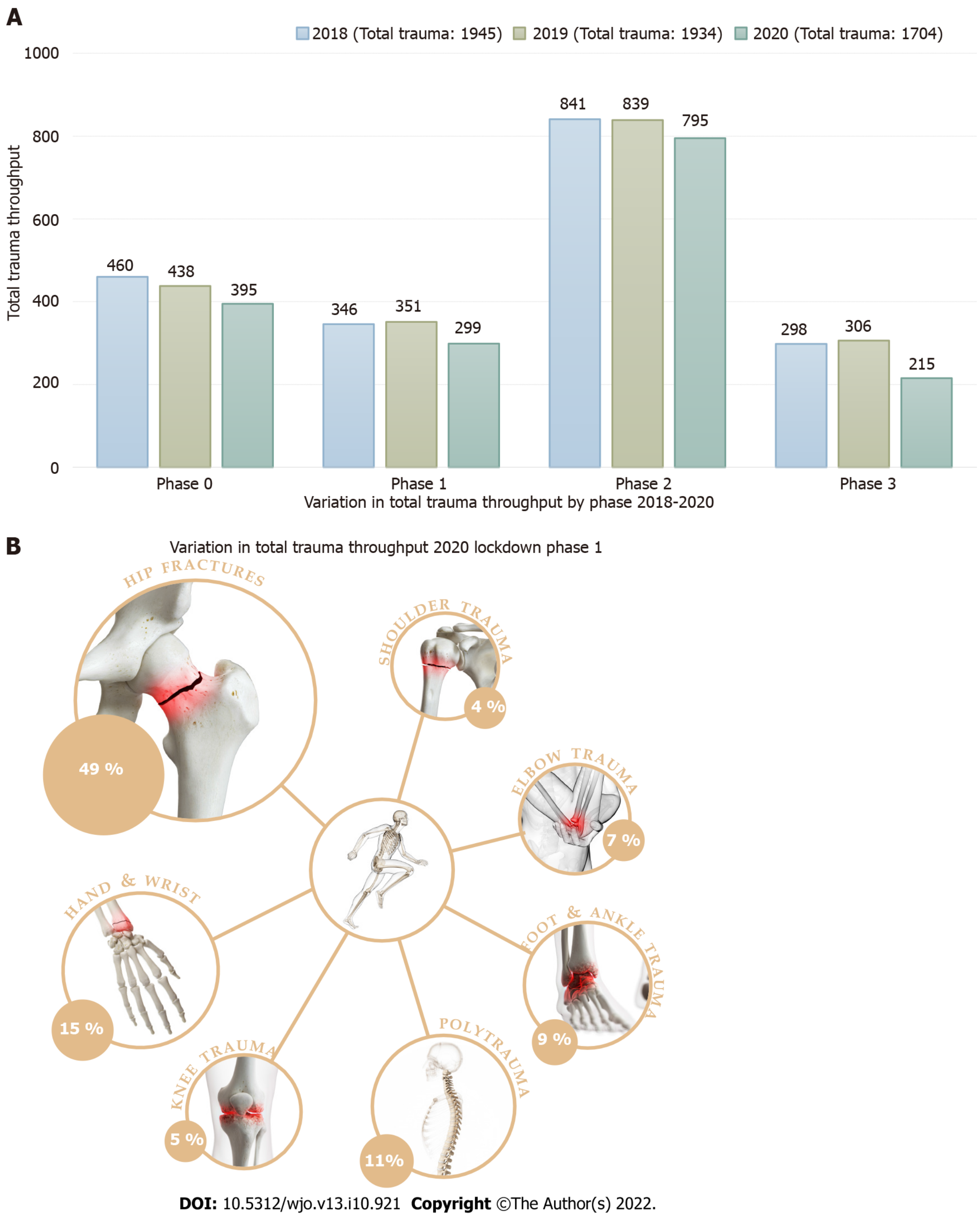

Figure 1 Variation in total trauma throughput. A: By phase; B: During the 2020 lockdown phase 1, images obtained *via* www.shutterstock.com using standard image licence agreement. (SciePro/shutterstock). Complete image exclusively designed and created by the authors.

thus resulting in an overall increased time in theatre.

Number of trauma operations per month

Figures 2A-C highlight the monthly variation in the highest throughput trauma sub-specialties (hip, hand & wrist, and foot & ankle). Consistent with previous years, hip fracture surgery encompassed the bulk of monthly surgical trauma, including the period affected by the COVID-19 pandemic. Supplementary Figures 1-4 highlights monthly variation in the remainder of the sub-specialties.

Qualitative analysis of changes to trauma care delivery

The pandemic ushered in several significant changes to the way in which trauma care was delivered (Figure 2D). Alongside the key changes described below, other changes that impacted our department included partial redeployment of all Orthopaedic Specialty Registrars to the intensive care units, and cessation of all but selected urgent elective cases (*e.g.*, infected arthroplasty). Structured colleague

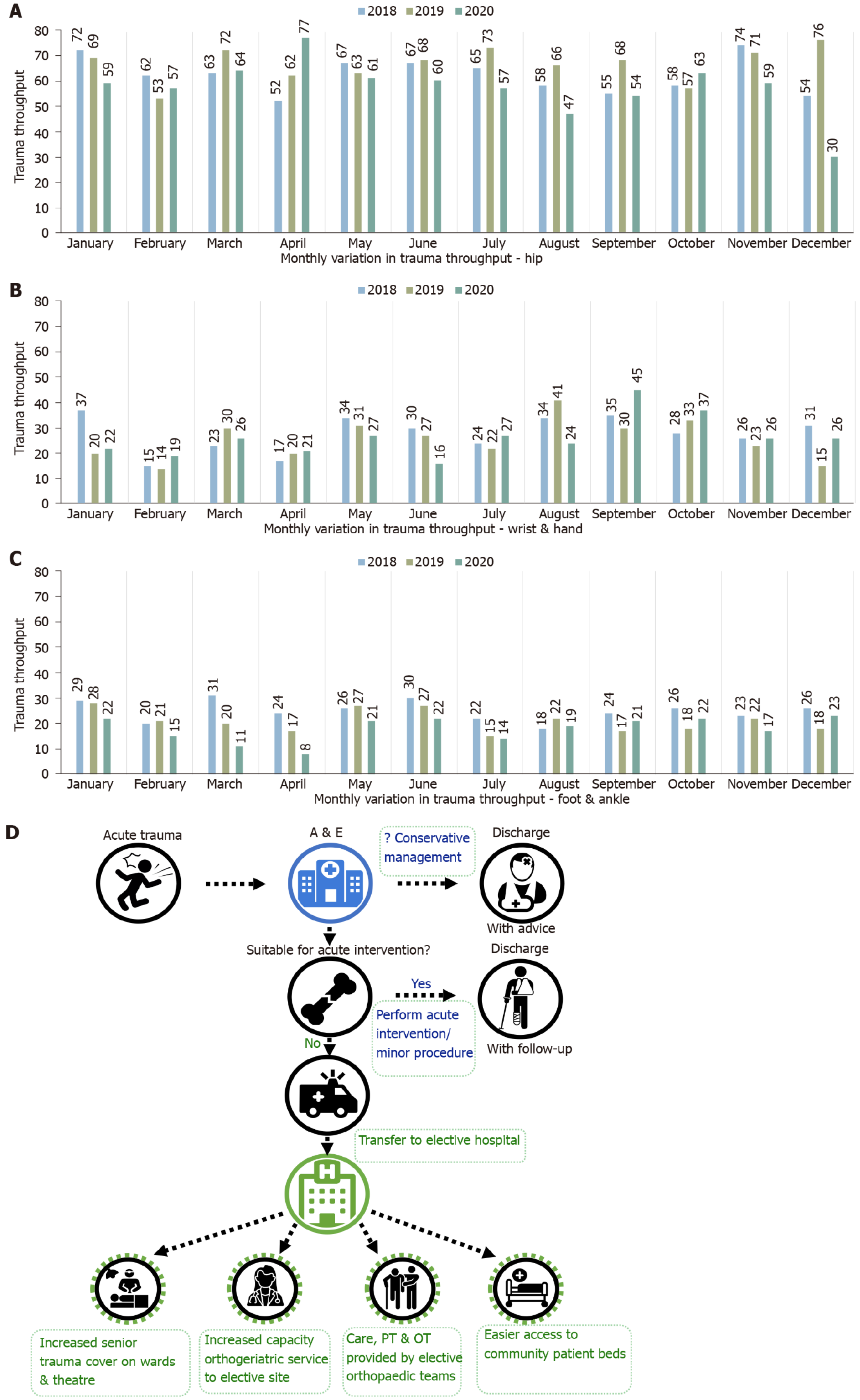

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Figure 2 Monthly variation in trauma throughput. A: Hip; B: Wrist & hand; C: Foot & ankle; D: Infographic, icons made by Freepik, icongeek26, iconmas and uniconlabs from www.flaticon.com and www.pngwing.com. Complete image exclusively designed and created by the authors.

interviews provided valuable MDT insight into what worked, and what was less successful.

Trauma care shift to our elective site: Patients requiring admission from the emergency department (ED) at our acute site were transferred by ambulance to our elective orthopaedic site to free capacity for COVID-19 admissions. Clinical staffing cover was accordingly adapted to ensure patient safety and prompt senior decision making. This transition was made swiftly and successfully as soon as elective activity was suspended, also lowering the exposure of our trauma patients to COVID-19.

Ward based nursing care and therapy provided by elective orthopaedic teams: The strategies adopted by these teams included similar protocols to the equivalent elective group (*e.g.,* early mobilisation regimes for total hip replacement patients applied following hip fracture surgery). Adopting more 'dynamic' approaches, with multiple therapy sessions per day, helped get patients safely mobilising sooner and facilitated discharge.

Transfer of increased capacity orthogeriatric service to elective site: Daily consultant-led ward-rounds facilitated rapid pre-operative stabilisation of patients with fragility femur fractures, alongside reduced surgical delay and LOS.

Easier access to community patient beds: Facilitated in conjunction with our community teams, a rapid electronic referral method was adopted during the pandemic, accelerating the request process for community beds and enabling more rapid discharge of patients that were 'medically' well but in need of rehabilitation prior to discharge home.

Increased senior trauma cover: Trauma care was led by a combination of our elective and trauma orthopaedic consultants and higher specialty trainees, working flexibly as required, with shadow rotas made to provide enhanced sickness cover. Whereas our usual trauma care is led by individual consultants' teams, supported by a supporting 'hot' floating consultant, the COVID-19 strategy involved a named consultant providing daily ward rounds of all admitted trauma patients, 7-d a week. This allowed issues to be identified and addressed early. In particular, weekend inpatient reviews facilitated on-day weekend discharges and preparation for anticipated Monday discharges.

Virtual clinics: While face-to-face elective clinics were significantly reduced, virtual telephone consultations were adopted. These were initially successfully applied to elective care, and thereafter to our trauma fracture clinics, enabling these acute services to reduce face-to-face contact, while maintaining overall throughput.

DISCUSSION

The COVID-19 pandemic has had a significant impact on both, our clinical ability to effectively manage trauma, as well as the way in which our patients have accessed trauma care. This has resulted in a paradigm shift in practice for the delivery of our trauma service, with many evolving changes and adaptations likely to leave their impression upon how healthcare will be provided in the future. Several centres across the United Kingdom.

This service evaluation project provided a quantitative and qualitative assessment of collective trauma throughput during four pre-determined phases, comparing throughput with the same periods in 2019 and 2018. Evaluation of phase 1 (*i.e.,* the 'lockdown' phase spanning 70 d) highlighted several important learning points. One of the expected key findings was that overall trauma throughput during phase 1 was reduced compared to 2019 and 2018 (299 procedures in *vs* 351 and 346, respectively). Despite this, hip fragility fracture numbers remained static at 146 procedures in both 2020 and 2019, still accounting for the bulk of the surgical workload during the lockdown phase (48.8% *vs* 41.6% *vs* 37.9%). There was a 45% reduction in the number of foot and ankle procedures between the 2020 phase 1 and its equivalent in 2019 as well as 2018 (26 procedures *vs* 47 *vs* 60). Similarly, hand procedures saw a 19% reduction compared to 2019 and 2018 (44 procedures *vs* 54 *vs* 53). There was no variation in polytrauma in phase 1 between 2020 and 2019 (32 cases).

Interpretation of these findings are suggestive of a reduction in overall emergency trauma presentations (which was anticipated in view of United Kingdom Government restrictions) and a shift towards more conservative measures for selective trauma, in keeping with updated national COVID-19 British Orthopaedic Association Standards for Trauma guidance[8]. For certain subspecialties (for example, foot and ankle, or hand and wrist), the nature of the trauma was conducive to more early interventions performed at presentation in the ED, without the need for admission and operative intervention.

A decrease was also observed in the overall mean LOS during phase 1 (5.69 d *vs* 7.50 *vs* 6.84). While successful approaches to determine (and reduce) the LOS through hospital are determined on mapping patient flow, replicating and understanding care models adopted by subspecialties during phase 1 to facilitate early discharge could have significant long-term benefits. Reducing the LOS has the potential to provide an effective means of containing and bridging the gap between service demand and resource constraints, particularly during the pandemic. Maintained orthogeriatric ward cover, daily consultant ward presence, and improved availability of community beds played important roles in ensuring efficient management of hip fracture patients - the majority of the patient mix - and therefore those contributing most to LOS. Fewer outliers also facilitated more efficient patient management. Best Practice Tariffs for hip fragility fractures require prompt surgery and appropriate orthogeriatric involvement - both factors contributing to a shorter LOS[9]. Phase 1 in 2020 demonstrated a shorter LOS for these patients; if maintained in the post-COVID era, this could result in improved care and resource benefits for our trust.

Both the CCI and the ECI are useful tools to quantify the underlying comorbid disease status. Both indices were raised for the 2020 phase 1 cohort (CCI - 0.90 *vs* 0.84 *vs* 0.65; ECI - 1.55 *vs* 1.36 *vs* 1.09), suggesting that trauma service had more multi-morbid patients with non-communicable disease admitted and operated during the lockdown phase, whist the ‘fitter’ cohort stayed at home. This also correlates with the fact that hip fragility fracture surgery numbers remained static between 2019 and 2020. One theory to account for this is that the lockdown may have resulted in an overall reduction in the support system offered to vulnerable and multimorbid patients, who therefore had to manage in isolation, increasing their likelihood of sustaining a serious injury requiring operative intervention.

Limitations

We recognise that our study has several limitations. While every attempt was made to capture all trauma admissions, the total figures do not encompass all trauma presentations to the ED (for example, those patients who had interventions at presentation in ED and were subsequently discharged or followed up in clinic). However, we are confident that our figures do indeed represent the majority of inpatient trauma admissions. We were also potentially limited by the accuracy of coding of admitted patients and HISS data, which in turn would affect parameters such as the comorbidity indices. Finally, the local hospitals found themselves in an unusual position where partial restrictions were imposed for an extended period of time (54 d) due to the Leicestershire region being a higher risk area, which overlapped with phase 2, resulting in a lack of clear distinction between these phases.

Learning points

Based on our findings, we have made several recommendations that we will adopt locally going forward. We encourage other teams facing similar challenges to consider these factors to improve the care of trauma patients.

Dynamic elective approaches to care can reduce LOS: The ‘elective mindset’ of the LGH nursing/ physical therapy/occupational therapy teams yielded more expeditious post-operative rehabilitation our trauma patients, ensuring more rapid optimisation of a more comorbid cohort of patients and reduced LOS during phases 1 and 2.

Sustain the rising trend in safe non-operative management to reduce inpatient workload: This was a trend particularly observed in hand and wrist/foot and ankle trauma where the care pathways were altered in the face of rising COVID-19 cases. We have since capitalised upon this opportunity to change our combined ED fracture management pathways for certain injuries to facilitate an increase the number of interventions and minor procedures performed at presentation at the front door under either ketamine or Penthrox® (Methoxyflurane), utilising our 24-h availability of fluoroscopic guidance for adult patients with our mobile C-arm X-ray in fracture clinic.

Maintaining rapid re-education of skills: By rapidly adopting local versions of national PPE guidance and developing standardised algorithms and training pathways, we maintained the hours to surgery and the improvements in time in theatre metrics. Redeploying these training pathways *via* designated trained senior staff will be integral to a rapid response in the face of future challenges, including from another COVID-19 wave.

CONCLUSION

The impact of the COVID-19 pandemic on healthcare systems globally cannot be underestimated. As the growing body of evidence and best-practice advice during the pandemic evolves, clinical practices will undoubtedly need to adapt accordingly. Our study allowed us to evaluate, analyse, and compare local trauma throughput variation during the pandemic, thus developing targeted interventions utilising an ‘elective care model’. This culminated in a more streamlined trauma patient care pathway from admission to discharge. By incorporating these modifications to clinical practice into our ‘new normal’ of clinical practice, we hope to build on this opportunity from adversity to improve patient care going forward.

ARTICLE HIGHLIGHTS

Research background

Coronavirus disease 2019 (COVID-19) has necessitated adaptations in local trauma services, with implementation of novel methods of practice, strategic changes, and shifting of resource management. Many of these changes may serve the driver for landmark changes to future healthcare provision. The pandemic environment is full of opportunities to capitalise upon to improve the flexibility of care provision for the benefits of both, patients and providers, with the ultimate aim of creating a long-term self-sustaining care model.

Research motivation

We sought to compare throughput and productivity metrics with preceding years to identify differences in practice that were successful, cost-effective, and sustainable. Should these changes prove successful, they may yield more sustained differences to the way we deliver care in the future.

Research objectives

By evaluating changes to practices implemented due to COVID-19 at our trauma unit, our goal was to evaluate those changes that were successful, cost-effective, easily adapted by clinicians, and deemed sustainable for the future, with a view to sharing our learnings more widely.

Research methods

We performed a comprehensive retrospective analysis of the objective impact of COVID-19 on our local trauma service provision, by comparing 2020 metrics with the equivalent 12-mo time periods in both 2019 and 2018.

Research results

Of 1704 cases were admitted in 2020, 11.9% and 12.4% fewer than 2019 and 2018, respectively. Hip fractures remained the bulk of surgical workload at the height of the pandemic. Mean length of stay was shorter during phase 1 (5.7 d). The time in theatre was longer (144.3 min) as a consequence of COVID-19 related measures that were introduced into theatre practice. Only the most co-morbid patients were admitted into hospital during phase 1, indicated by higher Charlson (0.90) and Elixhauser Comorbidity Indices (1.55).

Research conclusions

By evaluating, analysing, and comparing local trauma throughput variation during the pandemic, we developed targeted interventions utilising an 'elective care model' for more efficient trauma care.

Research perspectives

COVID-19 has resulted in a paradigm shift in how care is accessed and delivered, with many evolving changes and adaptations likely to leave an impression upon healthcare provision in the future.

FOOTNOTES

Author contributions: All authors equally contributed to this paper with conception and design of the study, literature review and analysis, drafting, critical revision, editing and approval of the final manuscript.

Institutional review board statement: This study was formally registered and approved by our Clinical Audit and Quality Improvement Team.

Informed consent statement: No individual patient consent was required as this study utilised unidentifable and anonymised grouped datasets.

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ORCID number: Kunal Kulkarni 0000-0002-9405-0273; Rohi Shah 0000-0001-9717-9825; Jitendra Mangwani 0000-0002-3960-3023.

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ORIGINAL ARTICLE

Clinical Trials Study

Traditional Chinese medicine ointment combined with tuina therapy in treatment of pain and swelling after total knee arthroplasty

Liang Xing, Hui-Rong Xu, Qing-Lin Wang, Hua Kong, Hua Zhang, Jing Tian, Ying Ding, Ru-Xin Yang, Lei Zhang, Bo Jiang

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Liang Xing, Hua Kong, Hua Zhang, Ru-Xin Yang, Lei Zhang, Bo Jiang, Department of Arthroscopy and Sports Medicine, Wangjing Hospital, China Academy of Chinese Medical Sciences, Beijing 100102, China

Hui-Rong Xu, Department of Nursing, Wangjing Hospital, China Academy of Chinese Medical Sciences, Beijing 100102, China

Qing-Lin Wang, Department of Vascular Surgery, Wangjing Hospital, China Academy of Chinese Medical Sciences, Beijing 100102, China

Jing Tian, Department of Orthopedics, Wangjing Hospital, China Academy of Chinese Medical Sciences, Beijing 100102, China

Ying Ding, Department of Spine, Wangjing Hospital, China Academy of Chinese Medical Sciences, Beijing 100102, China

Corresponding author: Bo Jiang, MD, Attending Doctor, Department of Arthroscopy and Sports Medicine, Wangjing Hospital, China Academy of Chinese Medical Sciences, No. 6 Zhonghuan South Road, Wangjing, Chaoyang District, Beijing 100102, China. arthrostudent@gmail.com

Abstract

BACKGROUND

The most effective treatment for knee joint pain is total knee arthroplasty (TKA), but the risk of pain and swelling in patients after surgery is high. Ice application, ankle pump exercise and non-steroidal anti-inflammatory painkillers are the primary clinical treatments after surgery. However, long-term use of non-steroidal anti-inflammatory pain relievers can easily cause gastrointestinal damage. Traditional Chinese medicine (TCM) ointments and tuina therapy integrate TCM and manipulation, which effectively promotes the penetration of TCM into the skin lesions, improves local blood circulation and inflammatory reaction and has good long-term effects on patients.

AIM

To evaluate the efficacy of TCM ointment combined with tuina therapy in the treatment of pain and swelling after TKA.

METHODS

The randomized controlled clinical trial enrolled 80 patients who underwent TKA *via* the same procedure. The patients were randomly divided among the treatment group (n = 40) and the control group (n = 40). The control group was given an analgesia pump in addition to oral painkillers as the postoperative intervention. The treatment group received TCM ointment with tuina therapy in addition to the analgesia pump and oral painkillers in the postoperative period. The following variables were recorded 3 d before surgery and 3 d, 7 d and 14 d after surgery: Visual analogue scale (VAS) score; skin temperature; circumferences at 15 cm above and below the patella; maximum active knee flexion angle; and the knee injury and Osteoarthritis Outcome score (KOOS).

RESULTS

After treatment, VAS was significantly lower in the treatment group than the control group at 7 d (t = 7.536, P < 0.001) and 14 d (t = 8.563, P < 0.001). The skin temperature of participants in the treatment group was significantly lower than that in the control group at 7 d (t = 2.968, P = 0.004) and 14 d (t = 4.423, P < 0.001). The circumference values of the two positions in the treatment group were lower than those in the control group at 7 d [t = 2.315, P = 0.023 (above); t = 2.121, P = 0.037 (below)] and 14 d [t = 2.374, P = 0.020 (above); t = 2.095, P = 0.039 (below)]. After 14 d of treatment, the maximum active knee flexion angle and KOOS of the two groups were significantly improved but were significantly higher in the treatment group (P < 0.05 for both).

CONCLUSION

TCM ointment and tuina therapy have significant advantages over standard care in the treatment of pain and swelling after TKA. This additional treatment may improve knee function but additional studies are needed to confirm our observations.

Key Words: Traditional Chinese medicine ointment; Tuina therapy; Total knee arthroplasty; Pain; Swelling

Core Tip: Traditional Chinese medicine (TCM) ointments and tuina therapy integrate TCM and manipulation, which effectively promotes the penetration of TCM into skin lesions, improves local blood circulation and inflammatory reaction, and has a good long-term effect on patients. This study observed and compared several parameters after artificial knee arthroplasty in two groups. The control group received routine care, and the treatment group received routine care as well as a TCM ointment and tuina therapy. All parameters were significantly better in the treatment group, providing evidence that the integrated therapy may improve knee function in the long term.

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INTRODUCTION

Knee osteoarthritis, also known as senile knee arthritis and hypertrophic knee arthritis, is one of the most common types of senile orthopedic diseases[1]. Long-term bone and joint wear decrease a patient's ability to move, including running, squatting and even walking. Currently, the most effective treatment for severe knee osteoarthritis is total knee arthroplasty (TKA)[2]. However, pain and swelling of the knee after the operation may impact rehabilitation and patient quality of life.

Treatments for the pain and swelling of the knee include ice compresses, ankle pump exercises, and non-steroidal anti-inflammatory analgesics. However, non-steroidal anti-inflammatory analgesics are not suitable for long-term administration, due to possible induction of gastrointestinal damage[3]. Rehabilitation methods, such as ice compresses and ankle pump exercises, can promote vasoconstriction and lymphatic return in the short term. Unfortunately, most patients remain bedridden for an extended period after surgery and have poor clinical compliance[4].

Traditional Chinese medicine (TCM) ointment combined with tuina therapy can effectively promote the penetration of TCM into the skin, improve local blood circulation and inflammatory response, and has good long-term efficacy for patients[5]. The primary objective of this study was to gain insight into the benefits of TCM ointment and tuina therapy to treat pain and swelling after TKA.

MATERIALS AND METHODS

Subjects

This study was a prospective study, and 80 patients (16 males and 64 females) were enrolled as research participants. All patients suffered from severe knee osteoarthritis and underwent TKA in the Fourth Department of Arthritis, Wangjing Hospital, China Academy of Chinese Medical Sciences between July 2021 and March 2022. Their age range was 56-82 years, with an average age of 68.18 ± 6.08 years. The average body mass index was 24.59 ± 2.69 kg/m^2. There were 47 cases with the left lower limb affected and 33 cases with the right lower limb affected. According to a random number table, the patients were divided into two equal groups of 40 patients, the treatment group and the control group. The general data of the patients in the two groups were not significantly different (Table 1). All patients signed an informed consent form, which was approved by the Ethics Committee of Wangjing Hospital, Chinese Academy of Chinese Medical Sciences.

Inclusion criteria were as follows: (1) Met the diagnostic criteria for knee osteoarthritis and TKA[6]; (2) Age from 60 years old to 80 years old; (3) Voluntarily participated in the study and signed the informed consent form; and (4) Postoperative limb pain and swelling were obvious with visual analogue scale (VAS) points ≥ 4.

Exclusion criteria were as follows: (1) Serious diseases, such as severe conditions of the cardiovascular, cerebrovascular or hematopoietic system, or mental disorders; (2) Severe dysfunction of the liver and kidney; (3) Autoimmune diseases, allergy diseases, and acute or chronic infectious diseases; (4) Postoperative complications; and (5) Skin damage, ulceration, allergy to TCM and skin diseases.

Patients were discontinued from the study if: (1) They had poor compliance or were not treated as prescribed; (2) They had incomplete data leading to the inability to evaluate the efficacy of the treatment; (3) They reported poor tolerance of the treatment; (4) They had deep vein thrombosis during the treatment; or (5) They showed drug allergy during treatment.

Study design

Both groups of patients received standard care after TKA. This consisted of patients being prescribed oral ibuprofen codeine sustained tablets, ice compress application continually for 72 h after the operation, and air pressure blood circulation apparatus utilization 20 min bid.

Patients in the treatment group received a TCM ointment and tuina therapy beginning on the 3rd d after the operation. The TCM ointment was applied to the acupoints of Zusanli (ST 36), Sanyinjiao (SP 6), Taichong (LR 3), Chengshan (BL 57), Shangjuxu (ST 37) and Futu (ST 32) on the affected side. Then, acupoint-tuina therapy was performed by pressing and rubbing each acupoint for 2 min. Next, local tuina therapy was performed by rubbing, kneading and scrubbing. The therapy was focused on the running parts of the meridians on the lower limbs, which includes the foot *yangming* stomach channel, the foot *taiyin* spleen channel and the foot *jueyin* liver channel. The treatment was applied for 20 min once a day for 14 d.

The TCM ointment was composed of Chuanxiong (*Rhizoma Chuanxiong*), Niuxi (*Radix Achyranthis Bidentatae*), Jixueteng (*Caulis Spatholobi*), Jinyinteng (*Caulis Lonicerae Japonicae*), Mangxiao (*Natrii Sulfas*), Moyao (*Myrrha*), Ruxiang (*Olibanum*), Huangqi (*Radix Astragali*), Shigao (*Gypsum Fibrosum*), Weilingxian (*Radix et Rhizoma Clematidis*) and Bingpian (*Borneolum Syntheticum*). These herbs were processed and mixed with paraffin oil petroleum jelly to make the ointment.

Observation factors

The following variables were measured on the third day before the operation and days 3, 7 and 14 after the operation, except for the knee range of motion and knee injury and Osteoarthritis Outcome score (KOOS), which were measured on the 3rd d before the operation and 14 d after the operation.

VAS score: Pain was evaluated by the VAS, with a total of 10 points (0-3 for mild pain, 4-6 for moderate pain, and 7-10 for severe pain).

Skin temperature[7]: The skin temperature of the patient's operation site [Zusanli (ST 36) acupoint] was measured.

Lower extremity swelling: The circumferences at 15 cm above and below the patella were measured with a tape measure. The measurement was repeated three times and averaged.

Range of motion and KOOS[8]: The knee range of motion and KOOS were used to evaluate the patient's pain, exercise, entertainment, quality of life and other items, with a total score of 100 points. The higher the score, the better the recovery of the patient's knee joint function.

Table 1 Comparison of general data between the treatment and control groups

Group	Sex, M/F	Age (yr)	BMI in kg/m^2	Educational level, illiterate/primary school/senior high school/ junior college/college and university	Surgical limb, L/R
Treatment, *n* = 40	6/34	67.28 ± 5.51	24.44 ± 2.37	2/1/23/12/2/0	22/18
Control, *n* = 40	10/30	69.07 ± 6.54	24.92 ± 2.24	0/1/26/11/0/2	25/15
χ^2/t	1.250	1.332	1.020	6.227	0.464
P value	0.264	0.187	0.310	0.285	0.496

M: Male; F: Female; BMI: Body mass index; L: Left; R: Right.

Statistical analysis

All collected patient data were processed using SPSS 26.0 statistical software (IBM Corp., Armonk, NY, United States). Measurement data were expressed as mean ± SD (χ ± s), and qualitative data were expressed as frequencies. The measurement data were first analyzed for normality, followed by the *t*-test for those that conformed to the normal distribution and the rank-sum test for those that did not conform. Count data were compared using the χ^2 test. In the χ^2 test, if the sample size was ≥ 40 but the theoretical number of one of the grids was 1 ≤ T < 5, then the continuity corrected χ^2 test was used. If the theoretical number T < 1 or the sample size was < 40, then Fisher's exact probability method was used. All statistical analyses were based on two-sided hypothesis testing, and the test level was α = 0.05. Differences were considered statistically significant when $P < 0.05$.

RESULTS

VAS scores

There was no significant difference in the VAS scores between the two groups on the 3rd d before the operation and the 3rd d after the operation ($P > 0.05$). After the treatment, the VAS scores of the treatment group were significantly lower than those of the control group 7 d after the operation (t = 7.536, $P < 0.000$) and 14 d after the operation (t = 8.563, $P < 0.000$) (Table 2).

Skin temperature

There was no significant difference in skin temperature between the two groups at 3 d before or after the operation ($P > 0.05$). The skin temperature in the treatment group was significantly lower than in the control group on day 7 after the operation (t = 2.968, P = 0.004) and on day 14 after the operation (t = 4.423, P = 0.000) (Table 3).

Lower extremity swelling

There was no statistically significant difference between the upper and lower circumferences of the patients 3 d before and after the operation ($P > 0.05$). The circumference above and below the patella were significantly lower in the treatment group 7 d after the operation (t = 2.315, P = 0.023 and t = 2.121, P = 0.037, respectively) and 14 d after the operation (t = 2.374, P = 0.020 and t = 2.095, P = 0.039, respectively) (Table 4).

KOOS

There was no significant difference in the range of motion of the knee joint and the KOOS between the two groups before treatment ($P > 0.05$). Fourteen days after surgery, the range of motion of the knee joint and the KOOS of the two groups were significantly improved. The knee range of motion and KOOS of the treatment group were significantly higher than those of the control group ($P < 0.05$) (Table 5).

DISCUSSION

TKA is the primary treatment choice for patients with severe knee osteoarthritis as it can effectively relieve pain, improve knee function and improve quality of life[9]. However, the disadvantages of severe trauma due to the operation and many postoperative complications are a concern to patients[10]. Joint swelling and pain are the most reported complications caused by TKA. Ice is one of the most

Table 2 Comparison of visual analog scale scores between the two groups

Group	-3rd d	3rd d	7th d	14th d
Treatment, *n* = 40	6.75 ± 0.92	5.30 ± 0.79	2.57 ± 0.84	0.80 ± 0.93
Control, *n* = 40	6.60 ± 0.84	5.65 ± 0.80	4.00 ± 0.85	2.70 ± 1.04
t	0.758	1.965	7.536	8.563
P value	0.451	0.053	0.000	0.000

-3rd d: 3 d before the operation; 3rd d: 3 d after the operation; 7th d: 7 d after the operation; 14th d: 14 d after the operation.

Table 3 Comparison of skin temperature between the two groups (°C)

Group	-3rd d	3rd d	7th d	14th d
Treatment, *n* = 40	37.34 ± 0.28	37.21 ± 0.26	36.93 ± 0.21	36.63 ± 0.31
Control, *n* = 40	37.29 ± 0.34	37.24 ± 0.32	37.09 ± 0.27	36.94 ± 0.32
t	0.755	0.422	2.968	4.423
P value	0.452	0.674	0.004	0.000

-3rd d: 3 d before the operation; 3rd d: 3 d after the operation; 7th d: 7 d after the operation; 14th d: 14 d after the operation.

Table 4 Comparison of lower limb swelling between the two groups

	Group		*t*	*P* value
	Treatment, *n* = 40	Control, *n* = 40		
Upper circumference in cm				
-3 d	53.35 ± 4.94	51.83 ± 4.34	1.461	0.148
3 d	52.83 ± 4.91	51.51 ± 4.29	1.274	0.206
7 d	48.32 ± 4.57	50.53 ± 3.97	2.315	0.023
14 d	45.68 ± 4.69	47.96 ± 3.89	2.374	0.020
Lower circumference in cm				
-3 d	39.59 ± 3.58	38.16 ± 3.78	1.734	0.087
3 d	38.96 ± 3.55	37.50 ± 3.85	1.768	0.081
7 d	36.71 ± 2.95	39.21 ± 6.86	2.121	0.037
14 d	34.96 ± 2.96	36.70 ± 4.35	2.095	0.039

-3 d: 3 d before the operation; 3 d: 3 d after the operation; 7 d: 7 d after the operation; 14 d: 14 d after the operation.

popular interventions for these two complications. This method may ameliorate the inflammatory response, pain and edema because the permeability of blood vessels may decrease due to shrinking blood vessels at the surgical site[11]. However, in the process of icing, nurses must monitor the patient's blood supply, peripheral nerve sensation and skin temperature to avoid frostbite of the skin due to the low temperature[12,13]. Another widely adopted postoperative intervention is the ankle pump apparatus. It can significantly improve blood circulation and lymphatic return of the lower extremities to effectively prevent venous thrombosis. However, patient compliance can be unsatisfactory, or the patient may refuse the intervention due to postoperative pain[14,15].

In this study, the postoperative treatment was performed by applying a prepared TCM ointment and tuina therapy to the affected side. The pain, swelling and skin temperature of the patients in the treatment group were significantly better than those of the patients in the control group 7 d and 14 d after surgery. According to TCM, the association of ointment and tuina therapy can regulate qi and blood because they directly warm the meridians to unblock the congealing cold. This improves the function of the internal organs, reinforces healthy qi and eliminates pathogenic factors.

Table 5 Comparison of knee range of motion and knee injury and Osteoarthritis Outcome score between the two groups of patients

Group	Knee range of motion in degrees		KOOS score	
	-3rd d	14th d	-3rd d	14th d
Treatment, *n* = 40	95.23 ± 2.11	115.32 ± 2.12	65.83 ± 1.39	85.52 ± 0.82
Control, *n* = 40	95.14 ± 2.24	113.34 ± 2.16	65.73 ± 1.33	80.32 ± 1.13
t	0.185	4.138	0.329	23.556
P value	0.854	0.000	0.743	0.000

KOOS: Knee injury and Osteoarthritis Outcome score; -3rd d: 3 d before the operation; 14th d: 14 d after the operation.

The ointment was primarily composed of herbs that can activate blood and relieve stasis, such as Ruxiang (*Olibanum*) and Chuanxiong (*Rhizoma Chuanxiong*). The tuina therapy used in this study was an integration of various manipulation methods of traditional Chinese tuina, such as scrubbing manipulation, acupoint-pressing manipulation, rubbing manipulation and kneading manipulation. The application of these manipulations in a tender way can relax the tense muscles and release spasms. It can also promote the absorption of drugs, improve local blood circulation and accelerate the reduction of inflammatory reactions, thus achieving the purpose of eliminating swelling and relieving pain. At the same time, tuina therapy applied to local regions may bring the movement of the corresponding muscle tissue, resulting in the improvement of metabolism of inflammatory substances in local lesions. This action can induce the recovery of local capillary endothelial function and the enhancement of blood circulation in local lesions.

In this study, tuina therapy was applied to the acupoints on the patient's affected side. The acupoints were Zusanli (ST 36), Sanyinjiao (SP 6), Taichong (LV 3), Chengshan (BL 57), Shangjuxu (ST 37) and Futu (ST 32). Applying pressure to these acupoints can effectively improve muscle tension. Moreover, the manipulation of Zusanli (ST 36) and Sanyinjiao (SP 6) acupoints has a significant effect on the regulation of the liver, spleen and kidney and the alleviation of knee joint pain and lower extremity numbness[16]. The acupoint tuina therapy applied on the Taichong (LV 3), Chengshan (BL 57) and Shangjuxu (ST 37) acupoints can significantly improve atrophy and impediment (*bi*) of the lower extremities[17].

Tuina therapy conducted on a group of acupoints can promote the blood circulation of the lower extremities. Moreover, the therapy is conducted at a relatively quick frequency, which is adopted to reduce large-scale movements of the patient's bones and joints, and to reduce the damage caused by the manipulation. Treatment compliance is typically satisfactory because the scrubbing and kneading manipulation improves soft tissue relaxation of tendons and ligaments, which is soothing to the patient. Our results also indicated that edema was reduced in the treatment group 7 d and 14 d after surgery. Similarly, Tao *et al*[18] observed that the combination of ointment and massage manipulation had a positive effect on improving postoperative pain and edema.

CONCLUSION

TCM ointment combined with tuina therapy has significant advantages in treating pain, swelling, skin temperature and knee joint range of motion after artificial TKA. Additional studies with a longer follow-up time and larger sample size will confirm the benefits of adding this treatment to the postoperative care of TKA as well as determine the mechanism of action in reducing the inflammatory response.

ARTICLE HIGHLIGHTS

Research background

Total knee arthroplasty (TKA) is the preferred treatment for patients suffering from severe osteoarthritis. The pain and swelling of the knee after the operation may impact rehabilitation and patient quality of life. Routine care to treat these complications includes icing, ankle pump exercises and non-steroidal anti-inflammatory analgesics. However, there are drawbacks to these treatments.

Research motivation

The use of traditional Chinese medicine (TCM) ointments can warm meridians, regulate qi and blood, and improve viscera function. It can effectively relieve pain, significantly recover function, and significantly improve the quality of life. Tuina therapy has been shown to enhance the penetration of ointments and has a good long-term effect on patients.

Research objectives

This study aimed to identify a benefit to adding a TCM ointment and tuina therapy to routine care for TKA.

Research methods

The randomized controlled clinical trial enrolled 80 patients who underwent TKA and were divided into two equal groups. All patients received routine care, with the treatment group also receiving TCM ointment with tuina therapy. The following variables were recorded 3 d before surgery and 3 d, 7 d and 14 d after surgery: Visual analog scale score; skin temperature; and circumferences at 15 cm above and below the patella. The maximum active knee flexion angle and the knee injury and Osteoarthritis Outcome score were recorded before surgery and 14 d after surgery.

Research results

All measured variables were significantly improved in the treatment group compared to the control group, who only received routine care during the postoperative period.

Research conclusions

Treatment with a TCM ointment and tuina therapy for knee arthroplasty patients effectively promoted the local lesion site metabolism and blood circulation, and had a significant inhibitory effect on the local inflammatory response and oxidative stress response.

Research perspectives

Additional studies with a longer follow-up time and larger sample size will confirm the benefits of adding this integrative treatment to the postoperative care of TKA as well as determine the mechanism of action in reducing the inflammatory response.

FOOTNOTES

Author contributions: Jiang B contributed to the conceptualization and data curation; Xu HR, Wang QL, Kong H, Zhang H, Tian J, Ding Y, Yang RX and Zhang L contributed to project administration; Xing L contributed to writing, including review and editing, and project administration; and all authors read and approved the final manuscript.

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ORCID number: Bo Jiang 0000-0003-4043-7170.

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CASE REPORT

Derotational osteotomy and internal fixation of a 180° malrotated humerus: A case report

Katharina Elisabeth Wenning, Thomas Armin Schildhauer, Clifford Barry Jones, Martin Franz Hoffmann

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Katharina Elisabeth Wenning, Thomas Armin Schildhauer, Martin Franz Hoffmann, Department of General and Trauma Surgery, BG University Hospital Bergmannsheil Bochum, Bochum 44789, Germany

Clifford Barry Jones, Department of Orthopaedic Surgery, Creighton Medical School Phoenix, Phoenix, 85012, United States

Corresponding author: Katharina Elisabeth Wenning, MD, Doctor, Surgeon, Department of General and Trauma Surgery, BG University Hospital Bergmannsheil Bochum, Buerkle de la Camp-Platz 1, Bochum 44789, Germany. katharina.wenning@bergmannsheil.de

Abstract

BACKGROUND

Humeral shaft fractures are relatively common in adults. Rotational malalignment is reported as one complication but severe rotational deformity of the humerus is extremely rare. To our knowledge, only three cases of symptomatic humeral malrotation have been reported. There are sparse literature reports of humeral reconstruction correction.

CASE SUMMARY

We present a case of extreme rotational deformity of the humerus (180°) after humeral shaft fracture. The patient complained of pain and difficulties with activities of daily living. In addition, she found the deformity cosmetically unacceptable. Therefore, she was searching for surgical correction. Neurolysis of the radial nerve followed by derotational osteotomy of the humerus and internal fixation were performed. Postoperatively, the patient demonstrated transient iatrogenic radial nerve palsy which recovered completely during postoperative follow-up. The Disabilities of the Arm, Shoulder, and Hand score improved from 55 preoperatively to 16 at the final 2-year follow-up.

CONCLUSION

Single-stage radial neurolysis, derotational osteotomy and stable fixation is a feasible option to improve anatomic and functional problems of severely malrotated humeral shaft fractures.

Key Words: Humerus; Malrotation; Corrective osteotomy; Plate osteosynthesis; Radial nerve palsy; Case report

Core Tip: We present a case of extreme rotational deformity of the humerus (180°) after humeral shaft fracture. The patient complained about pain and difficulties with activities of daily living. A neurolysis of the radial nerve followed by derotational osteotomy of the humerus and internal fixation were performed. Postoperatively, the patient demonstrated transient iatrogenic radial nerve palsy which had complete recovery at 2 years postoperatively. The Disabilities of the Arm, Shoulder, and Hand score improved from a preoperative 55 to a final 16 at the final 2-year follow-up.

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INTRODUCTION

Humeral shaft fractures are relatively common, accounting for approximately 1%-5% of all fractures and 20% of humeral fractures in adults[1-2]. These fractures have been historically regarded as benign fractures; as such, most are managed nonoperatively with functional bracing. The assumption of benign nature is based on the robust blood supply of the humerus, its limited weight-bearing characteristics and the technical ease of splint application[3-4].

Upper extremity function is primarily dependent on the hand's ability to reach a desired point in space. Most studies of malalignment have focused on angulation[5-6]. Rotational malalignment has been reported as a possible complication of humeral shaft fractures, but considered normally tolerated and to not necessitate a surgical intervention. Nevertheless, extreme rotational deformity following humeral shaft fractures can occur and the recommended treatment for these entities has been rarely touched upon in the literature.

Herein, we describe a case of a 180° rotational deformity that developed after a midshaft humeral fracture that had been clinically addressed by nonoperative treatment which had resulted in shortening of the humerus, limited range of motion (ROM) of the shoulder, and flexion contracture of the elbow.

CASE PRESENTATION

Chief complaints

The patient complained of resting pain exacerbated with activities and severe limitations in activities of daily living. Furthermore, the cosmetic deformity was repulsive to her.

History of present illness

In 2009, the right-hand-dominant patient had sustained a traumatic left humeral shaft fracture which was treated nonoperatively. In 2019 at age 27, she was referred to our institution with severe malrotation of her left humerus associated with shortening of the upper arm and limited ROM of the shoulder and elbow. The patient complained about consistent pain which increases during activities and severe limitations of activities of daily living. Furthermore, the cosmetic deformity was repulsive to her.

History of past illness

There is no history of past illness.

Personal and family history

Personal and family history are not known.

Physical examination

Physical examination detected a rotational deformity of the left upper arm of 180°. In supine position, the palm of her left hand and her olecranon were facing up (Figure 1). The Patient's left arm was 5 cm shorter than her right (51 cm *vs* 56 cm). She complained of tenderness over the whole upper arm and movement-dependent pain in the shoulder region. No neurological deficits were diagnosed. Shoulder ROM was presented with only 80° of abduction (Table 1). The elbow demonstrated a flexion contracture of 85°. The patient's forearm was fixed in neutral with total loss of pronation and supination. Wrist ROM was about normal.

Table 1 Range of motion of the patient's left upper extremity

	Preoperative	Postoperative
Shoulder		
Flexion/anteversion	80°	140°
Extension/retroversion	20°	25°
External rotation	30°	30°
Internal rotation	60°	60°
Abduction	80°	80°
Adduction	10°	20°
Elbow		
Flexion	85°	90°
Extension	0°	0°
Pronation	0°	80°
Supination	0°	80°
Wrist		
Flexion	50°	50°
Extension	50°	50°
Radial deviation	20°	20°
Ulnar deviation	30°	30°

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Figure 1 Severe malalignment of the patient's left arm. A: The patient in the operating room demonstrating the extreme deformity of the left upper extremity; B: In the supine position the palm of her hand and her olecranon (red narrow) were facing up.

Laboratory examinations

Laboratory examinations were unnecessary.

Imaging examinations

Radiographic imaging of the left shoulder and humerus demonstrated a malunited humeral shaft fracture with extensive remodeling and consolidated fracture site (Figure 2A). In addition, the shoulder displayed classic signs of post-traumatic osteoarthritis (Figure 2B). Preoperative three-dimensional computed tomography (3D CT) imaging confirmed a 180° malrotation of the humerus (Figure 3).

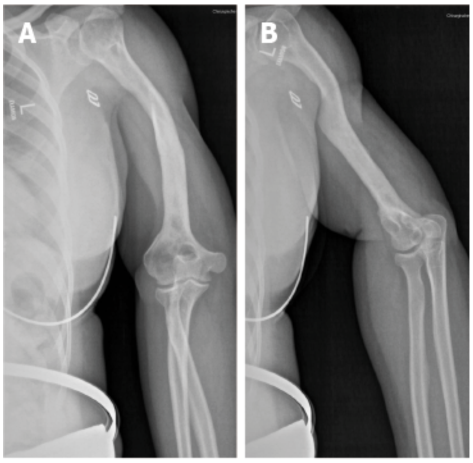

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Figure 2 Preoperative X-ray of the patient's left upper extremity. A: Preoperative X-rays of the left shoulder and upper arm of the patient revealed a deformed humerus and a complete consolidation; B: In addition, the X-ray displayed classic signs of post-traumatic osteoarthritis of the shoulder.

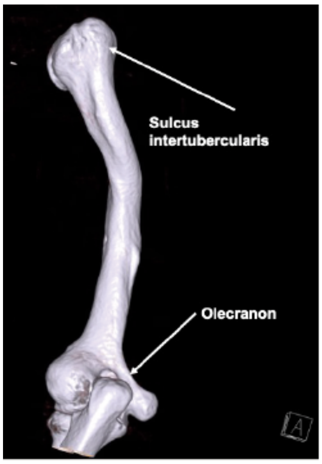

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Figure 3 Preoperative three-dimensional computed tomography of the patient's humerus. Extreme malrotation of 180° was detectable. The sulcus intertubercularis and olecranon served as landmarks.

FINAL DIAGNOSIS

The patient demonstrated with rotational deformity of the left upper arm of 180°. Imaging of the left shoulder and upper arm revealed a malunited humeral fracture with extensive remodeling and fracture site consolidation.

TREATMENT

Preoperatively, different surgical options were discussed with the patient and her family. The patient gave informed consent for a single staged procedure with complete radial nerve neurolysis followed by corrective osteotomy and internal fixation *via* plate fixation.

Ten years after the initial injury, the patient finally underwent derotational osteotomy with internal fixation of the left humerus and radial nerve exploration. Surgery was performed in the supine position under brachial plexus blocking and general anesthesia. Proximal humerus and the humeral shaft were exposed through a deltopectoral approach with extension distally anteriorly, following the anatomic muscles of the upper arm. Through the same anterior extensile incision, the radial nerve was exposed and released from the posterior aspect of the deltoid, through the lateral intermuscular septum, to the distal the arm in order not to lessen tension during the humeral derotation. A transverse osteotomy at the level of the consolidated fracture was performed carefully with a micro-oscillating saw and using instruments to protect surrounding and posterior soft tissues (Figure 4A). Subsequently, the entire distal

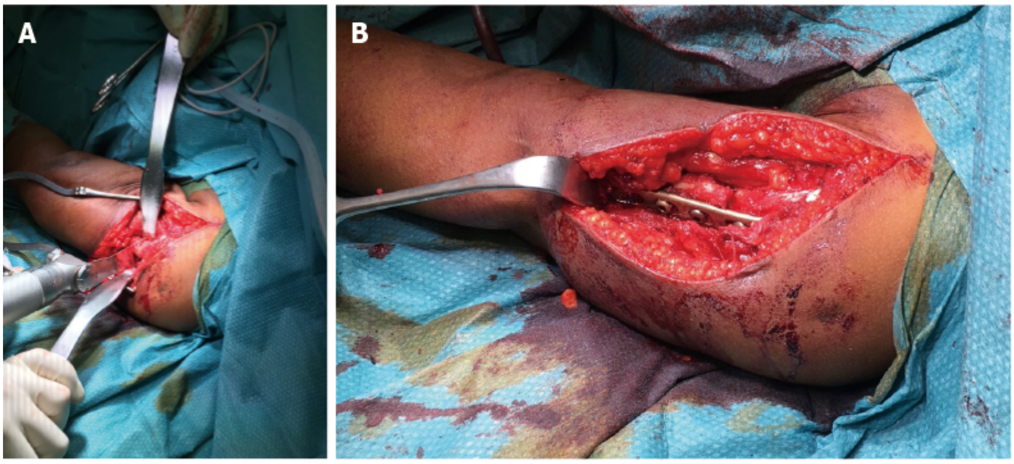

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Figure 4 Intraoperative photographs. A: Transversal osteotomy of the humerus was performed at the level of the former fracture; B: Internal fixation was done with the use of an eight-hole dynamic compression plate (Limited Contact Dynamic Compression Plate System).

humerus was rotated 180° demonstrating no tension to the radial nerve under direct visualization. Finally, internal fixation was performed utilizing an (3.5 mm or 4.5 mm) eight-hole dynamic compression plate [Limited Contact Dynamic Compression Plate System (LC-DCP); DePuySynthes, Warsaw, IN, United States] (Figures 4B and 5). Postoperatively, normal vascularity was noted, and soft compartments were noted, but a secondary or iatrogenic partial radial nerve palsy with weak wrist and digit extension and decreased light touch sensation in the radial nerve distribution. This injury was related to devascularization from dissection and manipulation of the nerve and less likely from the preoperative brachial plexus regional block. Secondary to the known intact and not impinged radial nerve at the end of the procedure, the patient and surgeons agreed to treat this transient radial nerve palsy with observation and did not re-explore the dissection.

The osteotomy zone was immobilized utilizing a Gilchrist-bandage for 4 wk postoperatively. Physical therapy with shoulder mobilization was initiated immediately after surgery. Shoulder and elbow ROM gradually increased and full ROM was allowed after 6 wk. Additionally, the weakened wrist muscles were immobilized in a functional splint and daily passive exercises were performed to maintain full ROM and to avoid contractures.

Initially, the skin incision had healed uneventfully and no signs of superficial or deep surgical site infection were noted. However, approximately 4 mo postoperatively, the patient presented with a deep surgical site infection with involvement of the osteosynthesis material and a non-consolidated osteotomy zone (an infected nonunion with fixation failure). Since the patient was healthy without comorbidities, she wanted to continue with therapy and avoid recurrence of the deformity. Therefore, a single stage revision was reviewed with the patient. Operative treatment consisted of plate removal with thorough excisional debridement, recanalization of the humerus, followed by re-osteosynthesis as a single staged procedure. Aerococcus viridans bacteria were detected in the deep intraoperative tissue cultures. Therefore, an antimicrobial therapy with clindamycin was initiated and continued for 6 wk.

OUTCOME AND FOLLOW-UP

After revision surgery, the patient did not present for follow-up appointments. We assumed that she was satisfied with the operative outcome and had resolution of the infection and preoperative functional difficulties. Approximately 2 years after initial surgery, we contacted the patient and scheduled an appointment. She reported a high level of satisfaction, resolution of infection, diminishment of pain, and a complete return to daily activities and caring of her two toddlers. Physical exam demonstrated complete healing of the soft tissues and resolution of the infection and imaging demonstrated consolidation of the osteotomy zone (Figure 6). The patient only complained of pain in her left upper arm and shoulder when carrying heavy objects or after a strenuous day with constant use of her arm. She demonstrated increased shoulder ROM: flexion/extension 140-0-25°, abduction/adduction 80-0-20° and improved elbow ROM: flexion/extension 0-0-90°, with free supination and pronation. Compared to preoperative function, she demonstrated a marked improvement in all areas of arm motion. She did not have full shoulder ROM secondary to the preoperative, degenerative changes of her left shoulder (Figure 7). The patient described gradual improvement in the radial function within 3-4 mo of the initial surgery with complete recovery of the transient radial nerve palsy at the time of the follow-up examination. The patient completed the follow up Disabilities of the Arm, Shoulder, and

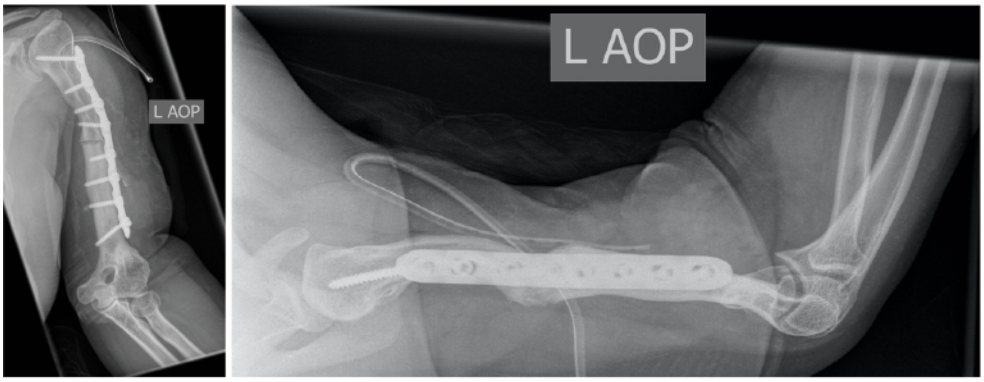

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Figure 5 Postoperative X-rays of the patient's left humerus after corrective osteotomy and internal fixation.

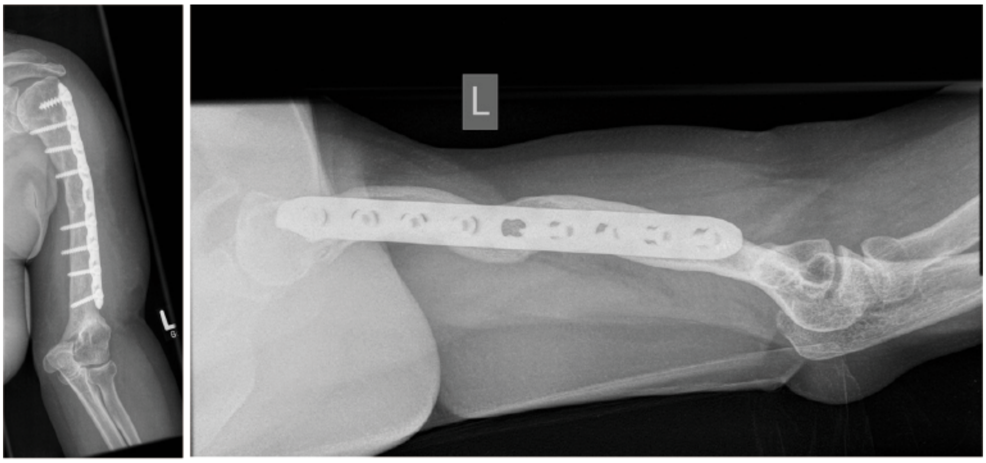

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Figure 6 X-rays at the patient's 2-year follow-up appointment. There was complete consolidation of the osteotomy zone.

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Figure 7 Postoperative cosmetic and functional outcome.

Hand (DASH) questionnaire comparing the pre- and post-operative scores. The DASH score improved from a preoperative score of 55 to 16 at the final follow-up.

DISCUSSION

Although rotational malalignment is recognized as a possible complication of humeral shaft fractures in adults, extreme rotational deformities are extremely rare. Accordingly, the literature regarding this topic is sparse. To our knowledge, only three cases have been reported[7,8] and there are only a few papers regarding upper limb correction in general, with most focusing on non-traumatic and pediatric indications[9,10]. In contrast, deformity correction and bone lengthening of the lower extremities are standard techniques with an increasing number of reports appearing in the literature. External fixators (unilateral, multiaxial, or circular) are utilized. Bulky techniques, like Ilizarov external fixation or Taylor-Spatial-Frame are still practiced and offered as reliable treatment options[11,12]. For upper limb treatment, circular fixation techniques like the Ilizarov external fixator and Taylor-Spatial-Frame pose problems of discomfort because of the limited distance to the thorax. Additionally, proximal or midshaft humeral fractures provide only limited bone stock for proximal fixation for all external fixation systems.

In our patient, the indications for operative intervention were the cosmetically unacceptable condition of a 180° malrotated arm as well as the inability to perform routine daily activities. She also reported limited ROM and severe pain of her left arm during shoulder movement. More extensive deformity corrections are usually performed as staged or continuous procedures utilizing external fixation to preserve neural structures and blood supply[13]. In our case, we decided against surgical correction by an external fixator for several reasons. On the one hand, the patient declined treatment with an Ilizarov fixator, citing the extensive follow-up care associated with it. Additionally, we needed a quick solution because it was unclear how long the patient would be in the area and available for follow-up and stepwise correction.

Although the patient's left arm already presented with a shorter length preoperatively, this condition did not bother our patient. Due to the decision just to perform a rotational correction and no lengthening of the arm, we chose derotational osteotomy, and exposure and release of the radial nerve by internal fixation. We assumed that exposing the nerve would reduce the risk for radial nerve injury. Nevertheless, the patient experienced radial nerve palsy postoperatively. Because of the good visualization of the radial nerve, we were able to rule out disruption or compression. There are reports of radial nerve injuries after deformity correction of the upper limb with different fixation systems[11,14] as well as after closed reduction of severe rotational deformity of the humerus[8]. Data on iatrogenic radial nerve injuries for open procedures vary between 6%-32%[15,16].

Regarding treatment, no clear consensus exists regarding if and when the nerve should be surgically explored[17]. Some authors recommend early exploration in cases of secondary nerve palsy[18], others advocate observation for a 4-to-6-mo period[19,20]. According to the literature, secondary radial nerve palsy has a good overall recovery rate of 93%[21]. In our case, the "wait and see" strategy was sufficient as the patient achieved complete neurological recovery. An increasing improvement in the radial nerve palsy was observed already after 4 mo. Two years after the initial surgery, the neurologic deficit had completely recovered, but the exact time point remains unclear because of the discontinued follow-up visits.

Different treatment options for surgical site infections and infected nonunions during a single or staged procedure have been discussed[22,23]. Due to the fact that our patient presented with infection 4 mo postoperatively, nonunion with secondary infection was assumed. Wu *et al*[24] reported a preference for single-stage treatment to address infected nonunions with Ilizarov fixation. Since our patient was healthy without comorbidities, we respected her request to continue with the initial therapy in order to avoid external fixation or recurrence of the deformity. Therefore, thorough debridement and hardware exchange were performed as a single-stage revision. Olszewski *et al*[22] reported their support of such an approach, based upon their data showing that 78% of patients healed after an index procedure and were able to avoid external fixation.

Bae *et al*[25] also described a case of severe malrotation of the humerus after humeral shaft fracture. Similar to our treatment, those authors described the performance of a derotation osteotomy of the left humerus with internal fixation and exposure of the radial nerve. They also reported a good postoperative result without neurological deficits.

In our case, the patient benefited greatly from the surgical procedure. Her preoperative DASH score was quite high (at 55) and had improved significantly after the deformity correction (to 16). Her 180° malrotated left upper arm represented a cosmetic problem, serving as a mental burden and significantly impairing her functional activities of daily living. Therefore, our treatment aimed for correction of the deformity, improvement of function, pain reduction, and achievement of the desired cosmetic result. These goals were achieved with very good results. The humeral malrotation has been entirely corrected and the overall deformity was reduced. Above all, shoulder ROM (especially shoulder flexion: 80° *vs* 140°) and pronation/supination of the elbow (0° *vs* 80°) increased significantly due to a more anatomic position of the humeral head articular surface. Some limitations persisted due to pre-existing degenerative changes. Furthermore, the flexion contracture of the elbow could not be resolved because of the long existing malalignment of the upper limb.

The patient noticed relevant pain relief from "severe" (preoperative) to "no" or "mild" pain postoperatively. At the 2-year follow-up appointment, she was very satisfied with the result of the operation. She indicated that she occasionally has pain in her left arm while carrying heavy objects. Ultimately, she stated that she is now living a normal life with her children without limitations in her everyday activities.

Our case complements the sparse literature of extreme malrotation deformity of the humerus and illustrates that corrective osteotomy with internal fixation may be a feasible treatment approach to avoid uncomfortable circular external fixation and to reach good postoperative results. It is a valid method that improved outcomes following deformity correction. We admit that a stepwise procedure utilizing a fixator (*e.g.*, a Taylor-Spatial frame) would have offered the option of additional lengthening.

CONCLUSION

Malalignment after humeral shaft fractures often includes a malrotation component. Extensive rotational correction is rare and the literature is sparse. Common procedures for extensive alignment correction utilizing circular external fixations cause a great amount of discomfort, especially when utilized on the proximal or midshaft humerus. Acute rotational correction of 180° is feasible and can lead to good clinical results when performed carefully.

FOOTNOTES

Author contributions: Wenning KE helped with data collection, interpretation and writing the case report; Hoffmann MF contributed to study concept/design and data analysis; Jones CB, Schildhauer TA and Hoffmann MF helped with interpretation and contributed to the review of the final manuscript and final submission of the paper.

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ORCID number: Katharina Elisabeth Wenning 0000-0003-0044-8107; Thomas Armin Schildhauer 0000-0002-3232-9869; Clifford Barry Jones 0000-0003-0273-676X; Martin Franz Hoffmann 0000-0003-0194-1497.

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