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Ultrasound diagnosis of fractures in mass casualty incidents

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Abstract

The role of point-of-care ultrasound in mass casualty incidents (MCIs) is still evolving. Occasionally, hospitals can be destroyed by disasters resulting in large number

of trauma patients. CAVEAT and FASTER ultrasound protocols, which are used in MCIs, included extremity ultrasound examination as part of them. The literature supports the use of ultrasound in diagnosing extremity fractures both in hospitals and MCIs. The most recent systematic review which was reported by Douma-den Hamer *et al* in 2016 showed that the pooled ultrasound sensitivity and specificity for detecting distal forearm fractures was 97% and 95% respectively. Nevertheless, majority of these studies were in children and they had very high heterogeneity. The portability, safety, repeatability, and cost-effectiveness of ultrasound are great advantages when treating multiply injured patients in MCIs. Its potential in managing fractures in MCIs needs to be further defined. The operator should master the technique, understand its limitations, and most importantly correlate the sonographic findings with the clinical ones to be useful. This editorial critically reviews the literature on this topic, describes its principles and techniques, and includes the author's personal learned lessons so that trauma surgeons will be encouraged to use ultrasound to diagnose fractures in their own clinical practice.

Key words: Fracture; Point-of-care ultrasound; Diagnosis; Mass casualty incidents

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Core tip: The role of point-of-care ultrasound in mass casualty incidents (MCIs) resulting in large number of trauma patients is still evolving. Radiological workup of these patients is important. The portability, safety, repeatability, and cost-effectiveness of ultrasound are great advantages in these situations. Its potential in managing fractures in MCIs is not fully defined. Its role will depend on different factors. The operator should master the technique, understand its limitations, and most importantly correlate the sonographic findings with the clinical ones.

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INTRODUCTION

New developments in technology have tremendous impact on managing trauma patients in austere conditions. Occasionally, hospitals can be destroyed or be out of function being stressed with lack of power, large number of trauma patients, and a need for rapid triage^[1-3]. Mass casualty incidents (MCIs) occur when the medical needs of injured patients exceed the available medical resources^[4,5]. Radiological workup of these patients, in this scenario, is important for accurate diagnosis and triage. So, any disaster management plan should include radiological workup as an integral part of it with full engagement of radiologists^[6]. Trauma Computed tomography (CT) scan is not available worldwide and even difficult to transport to the pre-hospital setting. In contrast, high quality portable light ultrasound machines have been used in the pre-hospital setting^[6,7]. They have rechargeable batteries that can last up to 4 h^[3]. This is a great advantage compared with CT scans and conventional heavy X-ray machines. Point-of-care ultrasound (POCUS) is noninvasive, rapid, and repeatable and can be combined with clinical examination to make critical decisions in triage and resuscitation of shocked patients^[8,9].

BASIC PHYSICS OF ULTRASOUND

Piezoelectric crystals of the ultrasound probes produce ultrasound waves and receive them. When these waves pass through body tissues, they get reflected depending on the density of the tissues. On the brightness (B) mode ultrasound images, fluids will be black, soft tissues will be grey, fibrous tissues will be white without a shadow, and bones will be bright white with a shadow. Accordingly, the cortex of long bones will be a white line with a black shadow deeper to it (Figure 1). Reverberation artifact which appears deeper to the cortical hyperechoic white line occurs because ultrasound waves bounce between the transducer and the bone cortex. The white reverberation lines represent repetition of the cortical hyperechoic white line as picked up by the ultrasound machine. The distance between these lines are equal^[10] (Figure 1B). This simple principle is pivotal for mastering diagnosing fractures. Fractures will appear as a complete interruption of the hyperechoic cortical line of the bone or as a cortical defect (Figures 2 and 3).

TECHNICAL CONSIDERATIONS

High frequency linear probes (10-12 MHz) have high resolution and low depth of penetration. Accordingly,

they are used for diagnosing fractures^[10,11]. It will be easy to perform POCUS on long bones using the linear probe because it gets in direct contact over the long bone (Figure 1A). The patient is asked to point at the maximum point of pain. The finger of the examiner is gently passed over the area to define the suspected area of fracture. This may not be possible in children, geriatrics and unconscious patients. It is always advised to compare the injured region with the normal side especially in children. Starting with the normal side in children will assure them and avoid the pitfall of misdiagnosing ossification centers and epiphysis as fractures^[11]. One of the major technical difficulties encountered when detecting fractures of small bones is the irregularity of the bone surface. Accordingly, air may be present between the probe and the bone. Air gives very highly echogenic reflections (white) and can cause a barrier when performing ultrasound. Adequate gel should be applied between the ultrasound probe and skin to reduce the artifacts caused by air (Figure 4). Some may even use water bath as an ultrasound transmitter to reduce the air artifact and pain while examining the patient^[11]. Ultrasound is not recommended to be done on open fractures. The diagnosis is already clinically made; this will delay the management, may cause infection, and will be very painful.

ULTRASOUND IN MCIS

The benefits of using POCUS in MCIs are numerous. Multiple injured patients may need help in austere geographical locations where radiological investigations are not available. POCUS is of great value in these circumstances. Hand-held ultrasound units have been routinely used in hospital and pre-hospital settings as a normal practice with encouraging positive results^[7,12,13]. This has increased the experience in using POCUS outside the routine hospital practice in conditions mimicking MCIs. Furthermore, POCUS has been done on patients during helicopter transportation in an unstable environment^[14]. POCUS images were transmitted through satellite technology using the principles of telemedicine by evaluating images at distant centers^[15]. Despite reduced clarity, overall accuracy in remotely detecting pericardial and peritoneal free fluid was 86%^[15]. POCUS images have even been transmitted from the International Space Station to a remote-control center located on the earth yielding acceptable image quality to make clinical decisions^[16,17]. Smartphones have been recently used in transmitting ultrasound images which is a very attractive approach in MCIs^[18].

CLINICAL APPLICATIONS

ATLS have been advocated in many countries as the accepted guidelines in the management of multiply injured patients. This includes primary physiological survey (Airway, Breathing, Circulation, Disability, and

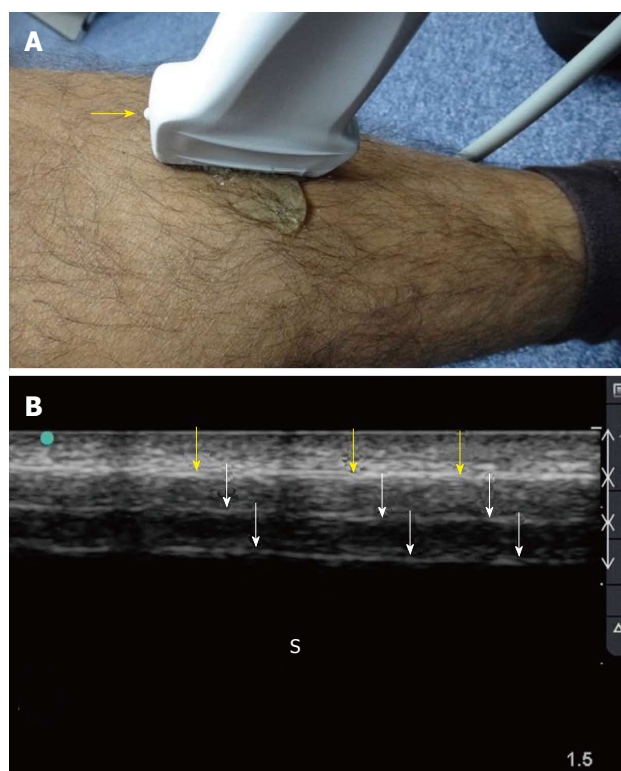


Figure 1 Ultrasound examination of the tibial shaft. A linear probe having a frequency of 10-12 MHz was used (A). The marker (yellow arrow) is pointing proximally. The plain surface of the tibia makes the examination easy. Normal ultrasound findings (B) include a hyperechoic line (yellow arrows) representing the cortical line of the bone. There are reverberation artifacts deeper to this line (white arrows). These are linear lines parallel to the cortex, having the same distance between them and decreasing in density. A black shadow is located deeper to that. S: Sonographic shadow of the shaft of the tibia. Ultrasound study was performed by Professor Fikri Abu-Zidan, Department of Surgery, Al-Ain Hospital, Al-Ain, UAE.

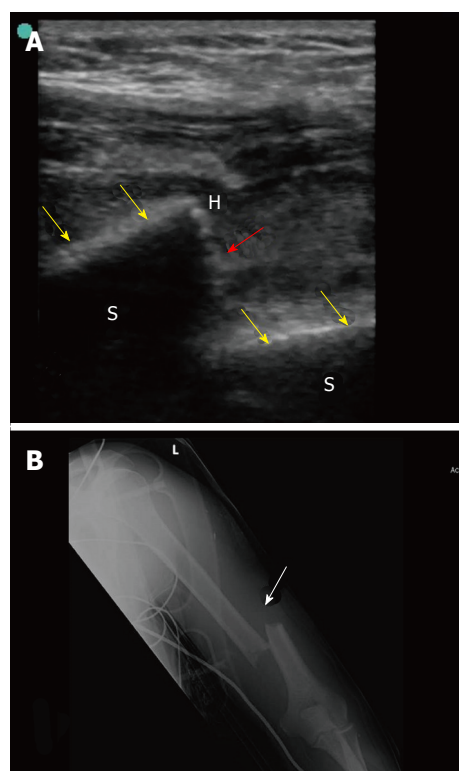


Figure 2 Point-of-care ultrasound of a 42-year-old laborer who fell from 8 meters high during work. The patient presented with pain, swelling and deformity of the left arm. He had left wrist drop. B mode point-of-care ultrasound of the humeral shaft using a linear probe having a frequency of 10-12 MHz (A) showed that the white cortical line of the humeral shaft (yellow arrows) has been interrupted by a large gap (red arrow) suggesting a displaced fracture at the shaft. X-ray of the humerus (B) confirmed the presence of a displaced fracture (white arrow). S: Sonographic shadow of the humeral shaft; H: Hematoma at the edge of the fracture. Ultrasound study was performed by Professor Fikri Abu-Zidan, Department of Surgery, Al-Ain Hospital, Al-Ain, UAE.

Exposure) for treating life-threatening conditions. This is followed by secondary survey which includes examining the patient from head to toe, front and back. POCUS has been very useful in the primary survey to define the source of shock in multiply injured patients^[19,20].

Diagnosing fractures by ultrasound should be part of the secondary survey. Certain protocols, like the CAVEAT protocol and FASTER protocol were developed to use portable ultrasound in the MCIs. They included extremity ultrasound examination in these protocols^[4,5,21]. The CAVEAT protocol (Chest, Abdomen, Vena cava, and Extremities for Acute Triage) included ultrasound extremity examination as part of the triage during the secondary survey^[4,5]. The FASTER protocol added the Extremity and Respiratory evaluation to the classical Focused Assessment Sonography for Trauma (FAST) examination^[21]. Hand held ultrasound could properly diagnose long bone fractures in military conditions^[22]. Dulchavsky *et al*^[21] used portable machines with linear probes in 95 patients who had extremity injuries (158 extremity examinations). Ninety-four percent of these patients were accurately diagnosed. Ultrasound can diagnose occult fractures that can be missed by conventional X-rays because it is very sensitive to

cortical defects^[5,23] (Figure 4).

May and Grayson^[24], in a Best Evidence Report published in 2009, critically appraised four papers. They reported that the results of using ultrasound to diagnose fractures of the wrist in children are very encouraging with high sensitivity reaching above 90%. Furthermore, they stressed the need for larger studies to prove their conclusions^[24]. A systematic review and meta-analysis, which was published in 2013, showed that ultrasound was accurate in diagnosing extremity fractures. This study searched MEDLINE and EMBASE during the period of 1965 to 2012^[25]. They included 8 studies in their final review. Six of these were in children. All studies used convenient, and not consecutive, samples. Ultrasound sensitivity for detecting extremity fractures ranged between 83% and 100%. The positive likelihood ratio ranged between 3.2 and 56.

An excellent recent systematic review and meta-analysis of high quality evaluated the diagnostic accuracy of ultrasound for distal forearm fractures^[26]. The authors searched PubMed, EMBASE and Cochrane database and included 16 studies in their final meta-analysis. Almost all studies used convenient samples but their overall quality was average to high. Majority

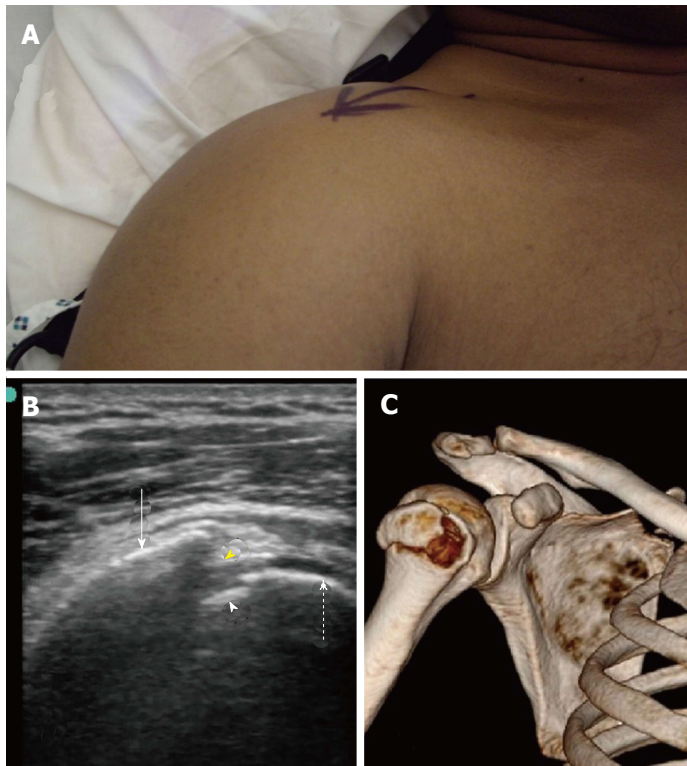


Figure 3 Point-of-care ultrasound of a 40-year-old front seat male passenger who was involved in a front impact collision with a tree. When presenting to the hospital, he had severe pain, swelling and limitation of the movement of the right shoulder (A). B mode point-of-care ultrasound of the right shoulder using a linear probe having a frequency of 10-12 MHz (B) shows that the humeral head (dashed arrow) and the greater humeral tuberosity (white arrow). There is a discontinuity of the bony line (yellow arrow head) indicating a fracture in the greater tuberosity. A small piece of fractured bone is also seen near the humeral head (white arrow head). Three-dimensional bony reconstruction of the right shoulder confirms the ultrasound findings (C). Ultrasound study was performed by Professor Fikri Abu-Zidan, Department of Surgery, Al-Ain Hospital, Al-Ain, UAE.

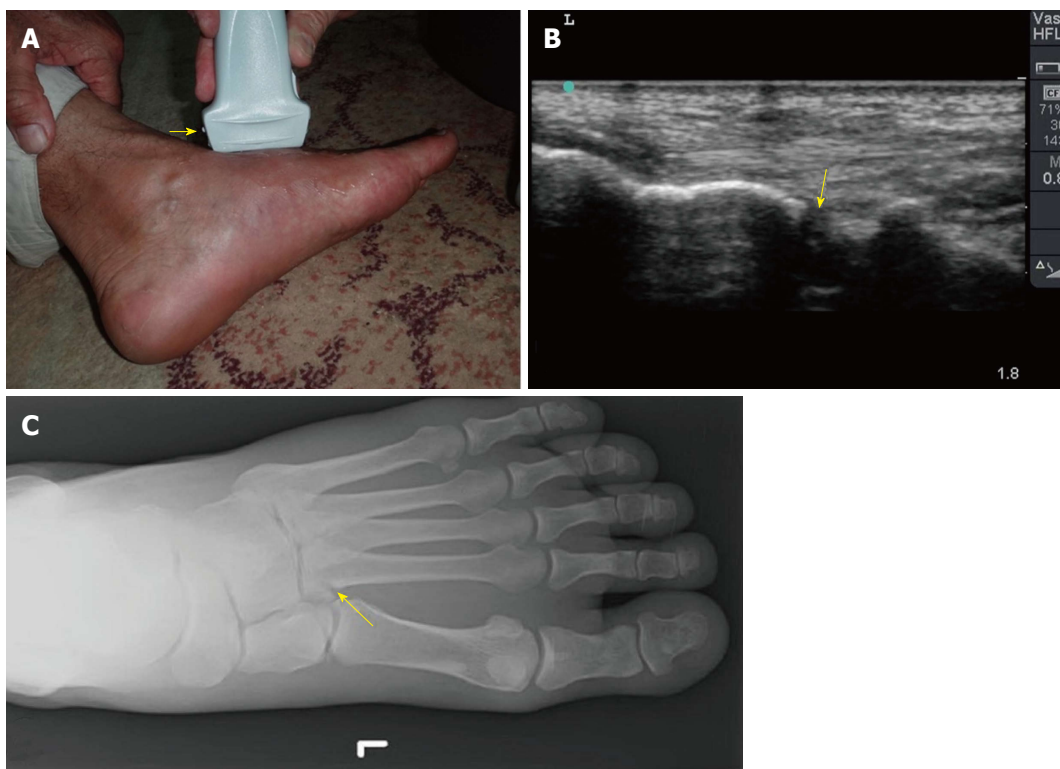


Figure 4 Point-of-care ultrasound of a 60-year-old man who twisted his left ankle and could not walk on it. He had swelling of the left foot with maximum tenderness on the base of second metatarsal bone (A). The yellow arrow indicates the marker of linear probe which is shown on the left side of the screen while the groove on the other side is shown on the right side of the screen. B mode images of the previous patient showed a cortical defect (yellow arrow) at the base of the second metatarsal bone suggestive of a fracture (B). Plain X-ray of the foot confirmed these findings (C). Ultrasound study was performed by Professor Fikri Abu-Zidan, Department of Surgery, Al-Ain Hospital, Al-Ain, UAE.

were in children. The pooled ultrasound sensitivity and specificity for detecting distal forearm fractures were 97% and 95% respectively. The positive likelihood

ratio was 20. Nevertheless, the heterogeneity of the sensitivity and specificity of the studies was very high (82% and 87%) with a very significant p value from the

chi-squared test ($P < 0.0001$).

POCUS TRAINING

The ultrasound guidelines for the American College of Emergency Physicians advocates the diagnosis of fractures by emergency physicians^[11]. According to the CAVEAT protocol, extremity assessment by ultrasound is one of the most difficult skills to be achieved^[4]. The results of ultrasound depend on three main factors: (1) training and experience of the operator; (2) quality of the machine; and (3) the studied region of the patient^[27]. Operators' experience in ultrasound varies tremendously which may dramatically affect its results^[28,29]. This is important when defining the role of ultrasound in MCIs. In principle, POCUS training should be incorporated into the surgical and emergency physicians training. Ultrasound training should include understanding the basic physics, instrumentation and image interpretation^[30,31]. Different methods have been used to achieve that including human models, patients, video clips, cadavers, simulation technology, and animal models^[29,32-34].

PERSONAL VIEW

Although the discussed principles in this article look easy, I find it occasionally difficult to diagnose very minor fractures. The main reason is that it takes time to do a full screening especially for minor fractures in seriously injured patients. This is a limitation which has been acknowledged by others^[6]. There is no doubt that POCUS is very useful to early diagnose fractures of long bone as they may cause shock. It is questionable whether diagnosing small bone fracture will have a long-term advantage on these patients.

Twenty-five years ago, no one would have imagined the place that POCUS will take in managing multiple trauma patients. The role of POCUS in MCIs in austere conditions is still evolving. Its potential is not yet fully defined. Its role in managing fractures will depend on different factors. The operator should master the technique, understand its limitations, and most importantly correlate the sonographic findings with the clinical ones. No doubt that portability, safety, repeatability, and cost-effectiveness of ultrasound are great advantages when treating multiply injured patients in MCIs. The technology is there but it is our duty to define its real value.

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Postoperative deep shoulder infections following rotator cuff repair

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Abstract

Rotator cuff repair (RCR) is one of the most commonly

performed surgical procedures in orthopaedic surgery. The reported incidence of deep soft-tissue infections after RCR ranges between 0.3% and 1.9%. Deep shoulder infection after RCR appears uncommon, but the actual incidence may be higher as many cases may go unreported. Clinical presentation may include increasing shoulder pain and stiffness, high temperature, local erythema, swelling, warmth, and fibrinous exudate. Generalized fatigue and signs of sepsis may be present in severe cases. Varying clinical presentation coupled with a low index of suspicion may result in delayed diagnosis. Laboratory findings include high erythrocyte sedimentation rate and C-reactive protein level, and, rarely, abnormal peripheral blood leucocyte count. Aspiration of glenohumeral joint synovial fluid with analysis of cell count, gram staining and culture should be performed in all patients suspected with deep shoulder infection after RCR. The most commonly isolated pathogens are *Propionibacterium acnes*, *Staphylococcus epidermidis*, and *Staphylococcus aureus*. Management of a deep soft-tissue infection of the shoulder after RCR involves surgical debridement with lavage and long-term intravenous antibiotic treatment based on the pathogen identified. Although deep shoulder infection after RCR is usually successfully treated, complications of this condition can be devastating. Prolonged course of intravenous antibiotic treatment, extensive soft-tissue destruction and adhesions may result in substantially diminished functional outcomes.

Key words: Rotator cuff repair; Deep shoulder infection; Shoulder surgery; Postoperative complication

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Core tip: Rotator cuff repair (RCR) has become one of the most frequently performed orthopaedic procedures during the last two decades. Paralleling the exponential increase in the number of RCRs, uncommon complications such as postoperative deep shoulder infections may be seen more frequently. Patients who are suspected to have a post-RCR infection require a thorough diagnostic evaluation, including clinical signs and symptoms, laboratory workups

and cultures. Although appropriate management of this condition with surgical debridement and lavage, and long-term IV antibiotics usually results in eradication of the infection, complications can be disabling and functional outcomes poor. The majority of the patients with deep infections after RCR report unsatisfactory outcomes with permanent functional limitations.

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INTRODUCTION

Rotator cuff pathology is one of the most commonly encountered orthopaedic problems, with an estimated prevalence of 17% to 35% including asymptomatic patients^[1]. In symptomatic patients, rotator cuff repair (RCR) usually provides good to excellent clinical outcomes^[1-4]. As a result, RCR has become one of the most frequently performed orthopaedic procedures during the last two decades^[5,6]. Paralleling the exponential increase in the number of RCRs, associated complications such as postoperative deep shoulder infections may be seen more frequently^[7]. Published literature indicates that the incidence of deep shoulder infection after open or mini-open RCR ranges between approximately 0.3% and 1.9%, and the condition is more common in male patients^[7-9]. While the rate of infection is generally thought to be lower after arthroscopic RCR, current high level evidence supporting this assertion is limited. In a recently published retrospective study including 3294 all-arthroscopic RCRs, Pauzenberger *et al*^[10] reported an infection rate of 0.85%. In another retrospective case series, Vopat *et al*^[11] studied the effects of surgical technique on infection rate. Out of 1824 RCRs performed by a single surgeon, 14 had an early deep postoperative shoulder infection that required surgical irrigation and debridement. Of these 14 patients who developed deep infections, primary RCR surgery was performed arthroscopically in only three of them, while 11 patients received open or mini-open repairs. The authors stated that "The most important finding in this study was that patients with non-arthroscopic RCR (open/mini open surgeries) had a greater risk [odds ratio (OR) = 8.63, $P < 0.001$] of infection compared with patients who had an all-arthroscopic RCR". It must be noted that all the available data in the literature consists of retrospective case series and that the patient records were reviewed based on follow-up notes or a re-operation registry for debridement^[7-11]. Hence, the actual incidence of infection may be higher, as many cases may go unreported due to patients choosing to seek treatment

at different institutions than where the primary repair had been performed.

RISK FACTORS

Risk factors for the development of suppurative infections of the shoulder joint can be summarized under three main categories: Anatomic, patient-related, and surgical technique or operating room (OR) environment-related risk factors.

Anatomic risk factors

The axillary area has been shown to provide an enriched colonization environment for various bacteria due to the presence of numerous sebaceous glands and hair follicles^[12-14]. Surgical incisions and entry portals for open, mini-open, and arthroscopic RCR are near the axilla, which may increase the possibility of inadvertent transmission of colonized microorganisms into the joint during surgery. Furthermore, precautions, such as clipping the axillary hair or preparing axillary skin with various solutions have not been proven to be successful in reducing infection rates or bacterial load^[15,16].

Patient-related risk factors

There are various patient characteristics that can adversely affect the body's defense against infections, including diabetes mellitus, immunosuppression, chronic diseases, advanced age, smoking, intravenous drug use, malnutrition, obesity, kidney and/or liver failure, and malignancies^[13,17,18]. In a retrospective comparative study from Chen *et al*^[18], three out of 30 (10%) type I diabetic patients developed infections following RCR. However, no patients in the non-diabetic group had infections after RCR. Pauzenberger *et al*^[10] found that age over 60 was an independent risk factor for post-RCR infections. In addition to systemic conditions, local factors, such as previous shoulder surgery and local corticosteroid injections, may also increase the risk of deep shoulder infection after RCR^[19,20].

Pauzenberger *et al*^[10] indicated that males are more prone to infection after RCR. The authors showed that out of 28 patients with deep infections after arthroscopic RCR, 27 (96.4%) were male and only 1 (3.6%) was female (OR = 21.41, $P = 0.003$). Likewise, Vopat *et al*^[11] reported that 92% of the patients in the infected group after RCR were male, compared to 58% of the control group patients who did not develop infections after RCR (OR = 9.52, $P = 0.042$). Although more male patients undergo RCR than female patients, this difference does not appear to be large enough to explain the significant difference in infection rates between men and women^[5]. Interestingly, there is evidence in the literature showing that *Propionibacterium acnes*' superficial skin colonization rate around arthroscopy portal sites was 81.6% in male patients and 46.1% in female patients^[21]. This colonization rate difference between men and women may be attributed

to the significantly higher serum testosterone levels in the male population vs the female population^[21,22].

Risk factors related to surgical technique and operating room environment

The risk of postoperative deep shoulder infection appears to be higher in open or mini-open RCR techniques compared with arthroscopic techniques^[1,11]. It is conceivable that the likelihood of bacterial contamination increases as the operation time and the size of the surgical incision increases. Another point worth considering is that open or mini-open RCR techniques have been performed much longer than arthroscopic repair techniques, which have only been performed for the last few decades. This fact, along with the improvement in disinfection and OR safety protocols, may have also influenced the decrease in infection rates for arthroscopic techniques^[23,24]. Nonetheless, there can be differences in the incidence of infection between various arthroscopic procedures. Yeranorian *et al.*^[17] reported that out of 165820 arthroscopic shoulder surgeries, 450 required additional surgery due to infections. The authors have noted that the incidence of infection was highest after RCR (0.29%) when compared with other arthroscopic procedures ($P < 0.01$). This finding underlines the significance of RCR as a procedure that increases the risk of infection, even when performed arthroscopically.

DIAGNOSIS

Clinical presentation

At the early stages, patients with deep infections after RCR usually present with increasing shoulder pain, stiffness, and, in some cases, loss of previously achieved postoperative range of motion (ROM)^[1,11,25-27]. There may be noticeable fibrinous exudate or pus drainage from the surgical wound and/or arthroscopy portals, with local swelling, erythema, and warmth around the shoulder joint^[7,8]. However, systemic signs and symptoms, such as fever, chills, low blood pressure, and generalized fatigue, are not common but they may be seen when there is a delay in presentation or when patients have immunosuppressive diseases.

Laboratory findings

Diagnostic lab workups to rule out or confirm deep shoulder infection after RCR include standard peripheral white blood cell (WBC) count with differential, erythrocyte sedimentation rate (ESR), and C-reactive protein (CRP) levels. Peripheral WBC count is usually within normal limits; however, ESR and CRP levels can be elevated. ESR and CRP levels are sensitive but not specific markers for deep shoulder infection. Athwal *et al.*^[8] studied 39 cases of deep shoulder infections after RCR and detected an elevated WBC count in only five patients (approximately 13%); ESR was available for 30 cases and was elevated in 18 cases (60%). The authors

checked CRP levels in 10 cases, and was elevated in five of them (50%). Kwon *et al.*^[7] reported similar results in a study including 14 patients with deep shoulder infections after RCR. In this study, the WBC count was measured in 10 patients, and nine of them had normal levels, averaging $7.6 \times 10^3/\mu\text{L}$ (range, $4.9\text{--}10.8 \times 10^3/\mu\text{L}$). The ESR was measured in eight patients and found to be elevated at least two-fold in seven patients (mean ESR value, $69 \text{ mm/h} \pm 32 \text{ mm/h}$). CRP was measured for two patients, and both were found to be increased, measuring 1.1 mg/dL and 7.7 mg/dL (normal, $< 0.8 \text{ mg/dL}$).

Glenohumeral joint aspiration and analysis with a cell count should be routinely performed in all patients presenting with a suspected deep shoulder infection. Aspirated fluid should also be examined microscopically for crystals, and a gram stain must be performed. As in most cases of septic arthritis, analysis of infected shoulder joint aspiration usually reveals a WBC count above $50000/\mu\text{L}$, with more than 75% polymorphonuclear leukocytes. These values indicate a deep infection of the shoulder, even if the gram stain returns negative and crystals are detected in the joint fluid. Aspiration fluid should be cultured in all cases, regardless of the results of cell count and the microscopic fluid analysis. Even though joint aspiration and synovial fluid analysis should be part of standard diagnostic work up for every case with a suspected joint infection, such data from patients with a reported deep shoulder infection after RCR is lacking in the literature.

Causative microorganisms

The most commonly isolated pathogens are, not surprisingly, the main species in sebaceous areas of normal skin flora, including *Propionibacterium acnes*, coagulase-negative *Staphylococci* (e.g., *Staphylococcus epidermidis*), and *Staphylococcus aureus*^[7-9,13]. However, infections due to various other microorganisms, such as *Corynebacterium* species, *Proteus mirabilis*, *Enterococcus faecalis*, *Peptostreptococcus magnus*, *Bacillus* species, *Streptococcus viridans*, *Actinomyces* species, and poly-microbial culture results, were also reported (Table 1)^[7-10,27].

Shoulder surgeons have recently focused on *Propionibacterium acnes* as a causative agent in many cases of deep shoulder infections after arthroscopic and open shoulder procedures. *P. acnes* is an anaerobic gram-positive bacillus densely colonized in the dermal skin layers around the head and shoulders. Despite routine preoperative antibiotic prophylaxis and skin preparation in shoulder arthroscopy, the rate of surgical site deep tissue inoculation with *P. acnes* can be as high as 19.6%^[21]. Furthermore, these patients were also found to have positive *P. acnes* superficial skin colonization that may indicate contamination by means of surgical instruments^[21]. Interestingly, Pauzenberger *et al.*^[10] reported that although administration of prophylactic antibiotics reduced the rate of infection

Table 1 Summary of reported microorganisms that were isolated from the patients with deep shoulder infections following rotator cuff repair in various retrospective case-series studies

Ref.	Patient No.	No. of isolated organisms	<i>P. acnes</i>	<i>S. aureus</i>	Coagulase-negative Staph ¹	Other microorganisms
Kwon <i>et al</i> ^[7]	14 (11 mono, 3 poly-microbial)	19	7	4	6	2 (<i>Proteus mirabilis</i> and <i>Enterococcus faecalis</i>)
Athwal <i>et al</i> ^[8]	38 (39 shoulders: 33 mono, 6 poly-microbial)	45	20	8	12	5 (<i>Corynebacterium species</i> × 2, <i>Peptostreptococcus magnus</i> , <i>Bacillus species</i> , <i>Streptococcus viridans</i>) 1 (<i>Peptostreptococcus</i>)
Settecerri <i>et al</i> ^[9]	16 (15 mono, 1 poly-microbial)	15	6	4	4	1 (<i>Peptostreptococcus</i>)
Pauzenberger <i>et al</i> ^[10]	28 (mono-microbial isolation in 23 patients)	23	8	2	12	1 (<i>Actinomyces species</i>)
Mirzayan <i>et al</i> ^[27]	13 (7 mono, 3 poly-microbial, 3 no growth)	15	3	5	5	2 (<i>Diphtheroids</i> and <i>Streptococcal species</i>)

¹Coagulase-negative *Staphylococci* include but not limited to *S. epidermitis*, *S. saprophyticus* and *S. hominis* (Courtesy of University of Manitoba, Section of Orthopaedic Surgery, Pan Am Clinic, Winnipeg, Manitoba, Canada).

from 1.54% to 0.28% ($P < 0.001$), there was no significant reduction in the rate of infections due to *P. acnes*. Further research is needed to study the correlation between superficial skin colonization and deep surgical tissue inoculation with *P. acnes* and postoperative deep shoulder infections following RCR.

Imaging

Radiographic evaluation in patients with deep shoulder infections after RCR is rarely necessary and usually reveals normal findings, particularly in acute cases. In subacute or delayed cases, ultrasonography and magnetic resonance imaging (MRI) with an intravenous contrast agent may be valuable to detect abscess formation around the shoulder joint or to identify complications, such as osteomyelitis^[13].

In rare cases, when the joint aspiration and culture results remain negative but the patient has clinical symptoms of infection, an indium 111-labeled WBC scan can be considered. Although this imaging modality might be helpful in localizing inflammation, it does not clearly distinguish between infectious and noninfectious inflammatory processes. Furthermore, reported sensitivity of indium 111-labeled WBC scans for the diagnosis of infectious conditions ranges from 60% to 100%, and specificity ranges from 69% to 92%^[28].

MANAGEMENT

Deep soft-tissue infections of the shoulder after RCR require a thorough and meticulous management that involves surgical debridement with copious lavage and long-term intravenous (IV) antibiotic treatment. Although this approach is universally accepted, the literature mostly provides evidence regarding open debridement due to the fact that the great majority of published studies are retrospective case series including patients who had either open RCRs or arthroscopically-assisted mini-open RCRs^[7-9,11,27]. However, studies indicate that arthroscopic RCRs have increased by

600%, while open repairs have increased by only 34% during the time interval between 1996 and 2006^[5]. It is highly possible that the percentage of arthroscopic RCRs have increased even further since 2006 compared with open repairs, as arthroscopic RCR has become the procedure of choice for the surgical treatment of rotator cuff pathologies. Hence, arthroscopic debridement and lavage needs to be emphasized as the primary surgical procedure to address acute deep shoulder infections after RCR.

Arthroscopic lavage and debridement

Any antibiotic treatment prior to surgery should be discontinued at least five to seven days before surgery. The importance of withholding lavage and IV antibiotics until obtaining cultures from the pus and debrided deep tissues cannot be overemphasized. In general, after the operative site is prepared and draped, incisions along the infected portals are made, and the pus from deeper tissues is drained through these portals. Cultures are then taken from the drained pus, and the swabs are used to obtain deep tissue cultures through the portals (Figure 1). It is advisable to start with a dry arthroscopy of the glenohumeral joint to achieve a better visualization of the infection and to obtain more tissues for culturing before the joint is washed (Figure 2). The glenohumeral joint and the previously repaired rotator cuff is assessed intraoperatively following the initial lavage. Ideally, all the suture material and anchors are removed, and the joint is washed profusely using a minimum of 10 L of fluid, with the last liter containing 100000 units of bacitracin^[27]. Although there could be variations in approach among individual surgeons, a re-repair of the rotator cuff during the same arthroscopic debridement and lavage procedure is not suggested before completing a long-term IV antibiotic therapy and confirming that the infection has been eradicated. In selected patients, based on intraoperative assessment, the sutures and anchors can be retained if the infection is not extensive and there is no loosening of the re-



Figure 1 Drainage from an infected arthroscopy portal immediately before the arthroscopic debridement and lavage. After anesthesia the patient is positioned and the shoulder is draped. An incision is made through the infected portal and cultures are taken from the draining pus. Additional deep tissue cultures are sent during the arthroscopic debridement (Courtesy of University of Manitoba, Section of Orthopaedic Surgery, Pan Am Clinic, Winnipeg, Manitoba, Canada).

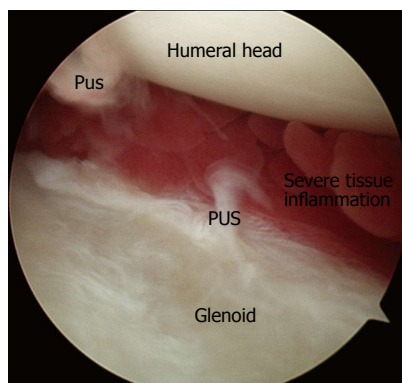


Figure 2 Arthroscopic view of the glenohumeral joint space from a patient with deep shoulder infection after rotator cuff repair. It is possible to visualize the pus and severe tissue inflammation before the irrigation (Courtesy of University of Manitoba, Section of Orthopaedic Surgery, Pan Am Clinic, Winnipeg, Manitoba, Canada).

paired cuff tissue.

Open debridement and lavage

Deep infection usually involves the surgical wound and forms a tract that connects the deep tissues to the superficial layers of the surgical incision. Hence, open surgical debridement and lavage is the mainstay of treatment in patients who had open RCR as the initial procedure. Athwal *et al.*^[8] treated 39 patients with post-RCR deep shoulder infections by means of an open irrigation and debridement (30 patients), and a combined arthroscopic and open debridement (nine patients). They reported that a mean of 3.3 surgical debridements were necessary for eradicating the infection. Between surgical debridements, the wound was left open and packed with sterile gauze in 18 shoulders and closed over a drain in 21. They used antibiotic-laden cement beads in five patients. In a series including 16 patients with deep infections after an open RCR, Settecerry *et al.*^[9] did an average of 3.5 open debridements (range two to eight debridements), and the wound was left open and packed with sterile gauze between the procedures. Other studies report a similar treatment approach to deep shoulder infection after open RCR^[7,27].

This evidence shows a tendency for multiple open debridement and lavage procedures in patients with deep infections after open RCR. Furthermore, leaving the wound open and packed with sterile gauze between debridements may also mean extended hospital stays for these patients that can negatively influence their quality of life and increase the economic burden on the healthcare system. Of note, patients with deep shoulder infections who underwent arthroscopic RCR as the initial procedure should also be treated with open debridement and lavage if complications such as osteomyelitis, abscess formation, or tissue necrosis exist.

Intravenous antibiotic therapy and infection follow-up

It is imperative to approach post-RCR deep shoulder infection as septic arthritis and to consider IV antibiotic treatment for a minimum of 4 to 6 wk to successfully eradicate the infection and to minimize the risk of complications, such as osteomyelitis, that may occur with a higher incidence due to the suture anchors placed in the humeral head. The antibiotic should be chosen based on the culture and susceptibility results and after a consultation with the infectious disease specialist who will be involved in the patient's management through the course of the initial treatment and the follow-up. A peripherally inserted central catheter must be placed and managed appropriately by regular flushing with normal saline between antibiotic doses to maintain patency. Depending on the causative microorganism and the patient's response to the initial treatment, IV antibiotic treatment can be supplemented or extended by oral antibiotics, as supported in the literature^[7-9].

The assessment of therapeutic response and follow-up of infection is mainly done by clinically evaluating the patient and monitoring infection markers, such as ESR and CRP. The duration of antibiotic treatment and the confirmation of infection eradication requires shared decision making between the orthopaedic surgeon and the infectious disease specialist.

COMPLICATIONS AND OUTCOMES

Deep infections of the shoulder after RCR are usually successfully eradicated with debridement and lavage, and long-term IV antibiotics^[7-9]. Nevertheless, devastating complications, such as osteomyelitis, abscess formation, post-infectious glenohumeral arthritis, and insufficient soft tissue coverage can be encountered, and functional outcomes may be far less than optimal. Kwon *et al.*^[7] reported a 67% dissatisfaction rate in a group of 12 patients treated for deep infection after RCR, with a mean UCLA score of 23.6 (excellent and good ≥ 28 , fair and poor ≤ 27). Among these patients,

two needed rotational muscle flaps due to insufficient deltoid tissue after repeated open debridements. Athwal *et al*^[8] reported a complication rate of 32% during the medical and surgical treatment of deep infection after RCR. Their series included one patient who required arthrodesis and two patients who underwent shoulder arthroplasty due to glenohumeral arthrosis within 66 mo of eradicating the deep infection. Mirzayan *et al*^[27] studied 13 patients with chronic deep infections following open RCR. Seven patients had osteomyelitis of the humeral head, two had osteomyelitis of the humeral head and the glenoid, two had osteomyelitis of the clavicle and the acromion, and two had no osteomyelitis but had a subdeltoid abscess. Seven patients required a rotational flap to allow for joint coverage. The results of the Simple Shoulder Test in this study revealed that only three patients could lift a one-pound weight (0.5 kg) and none could lift an eight-pound weight (3.6 kg) to shoulder level without bending the elbow. Eight patients could throw underhand; however, only one could throw overhead.

Although these studies clearly indicate that outcomes after an infected open or mini-open rotator cuff repair can be permanently disabling, no studies to date have reported the effects of deep infections after arthroscopic RCRs on functional outcomes.

CONCLUSION

Deep shoulder infections after rotator cuff repair are not frequently encountered. Patients who are suspected to have a post-RCR infection require a thorough diagnostic evaluation, including clinical signs and symptoms, laboratory workups and cultures. Although appropriate management of this condition with surgical debridement and lavage, and long-term IV antibiotics usually results in eradication of the infection, complications can be disabling and functional outcomes poor. Abscess formation, osteomyelitis, post-infectious glenohumeral arthritis, and loss of the soft tissue envelope are among the most devastating complications resulting from post-RCR deep infections. The majority of the patients with deep infections after RCR report unsatisfactory outcomes with permanent functional limitations.

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Synthesis of evidence for the treatment of intersection syndrome

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Abstract

Intersection syndrome is a rare sports overuse injury occurring through friction at the intersection of the first and second compartment of the forearm. Differential diagnosis must be carefully made, especially from De Quervain tendonsynovitis. Clinical examination provides with the necessary information for diagnosis, still magnetic resonance imaging scans and ultrasonography may assist in diagnosis. Treatment consists mainly of rest, use of a thumb spica splint, analgetic and oral nonsteroidal anti-inflammatory drugs and after 2-3 wk progressive stretching and muscle strengthening. Should symptoms persist beyond this time, corticosteroid injections adjacent to the site of injury may be useful. In refractory cases, surgical intervention is warranted.

Key words: Intersection syndrome; Overuse injury; Wrist pain; Differential diagnosis; Treatment

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Core tip: In this review, current aspects of clinical and imaging diagnosis, as well as therapeutic approach of intersection syndrome, are outlined. This overuse syndrome which may provokes significant wrist pain and disability, is associated with repetitive wrist flexion and extension and compressive forces applied to the wrist and is common in sports such as rowing, canoeing, skiing, weight lifting and racket sports. Conservative treatment is generally an efficient therapeutic approach and includes means such as rest, cryotherapy, immobilization through splinting, medication with non-steroid anti-inflammatory and corticoid drugs as well as individualized rehabilitation program incorporating progressive stretching and muscle

strengthening exercises. Future research is proposed to select larger samples if possible and utilize the frank value of imaging studies such as magnetic resonance imaging scans or ultrasonography as well as optimal therapeutic strategies for every individual suffering from this syndrome.

Balakatounis K, Angoules AG, Angoules NA, Panagiotopoulou K. Synthesis of evidence for the treatment of intersection syndrome. *World J Orthop* 2017; 8(8): 619-623 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v8/i8/619.htm> DOI: <http://dx.doi.org/10.5312/wjo.v8.i8.619>

INTRODUCTION

Although the first report of the IS took place by Velpeau in 1841, Dobyns in 1978 was the first who introduced this term^[1,2]. Intersection syndrome (IS) which has been alternatively named peritendinitis crepitans, crossover syndrome, adventitial bursitis, subcutaneous perimyositis with abductor pollicis longus syndrome and bugaboo forearm^[3-5] is a rare inflammatory condition, usually reported as an overuse injury resulting from friction between two compartments each wrapped in its own sheath. The dorsal or first musculotendinous unit/compartment contains the abductor pollicis longus and the extensor pollicis brevis while the second compartment includes the extensor carpi radialis longus and extensor carpi radialis brevis^[6]. These two compartments intercept at an angle of 60 degrees^[7]. Montechiarello *et al*^[1], specifically report that friction occurs between the muscle bellies of the first compartment and the tendon sheaths of the second compartment. Intersection syndrome has been also reported to result from stenosis and entrapment of the second compartment, although it has been supported that it is not clear which is the etiology of this pathology^[5].

Draghi and Bortolotto^[8] report that there is also an intersection more distally where the extensor pollicis longus intersects with the second compartment. Friction may occur at that site as well, resulting in intersection syndrome^[9-11]. Furthermore, the second compartment may also be not in a single sheath but each tendon may be in its own sheath^[4,12]. The flexor retinaculum has also been attributed a possibly important role in the pathogenesis of IS^[13].

Overall incidence ranges from 0.2% to 0.37% in various studies^[14]. IS occurs through repetitive wrist flexion and extension and compressive forces applied to the wrist^[15], affects mainly the dominant hand, and onset has been pinpointed specifically when beginning a new sport^[15]. This nosologic entity is reported in sports such as rowing, canoeing, horseback riding, skiing, weight training or racket sports, activities associated with repetitive wrist extension^[16,17]. In a study including 42 skiers, prevalence was estimated as high as 11.9%

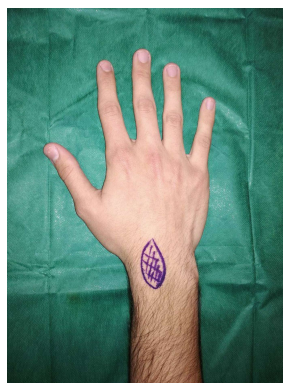


Figure 1 Area of pain and tenderness to palpation in intersection syndrome.

in the first two days^[18]. In another study, incidence reached 2% in tennis players^[11] whilst in a study of 8000 patients with arm or hand pain, occurrence was found to reach only 0.37%^[19].

In this review current aspects of clinical and imaging diagnosis as well as the therapeutic approach of IS are outlined.

CLINICAL EXAMINATION

Clinical examination reveals usually pain 4-8 cm proximally to radial styloid and swelling in the radial aspect of the wrist and forearm^[20] (Figure 1). Localized redness and tenderness to palpation over the site of swelling are two other typical clinical signs^[20]. Pain in movement is observed specifically in ulnar deviation and wrist extension. Crepitus in palpation during flexion and extension of the wrist may also be present^[1,17].

DIFFERENTIAL DIAGNOSIS

Differential diagnosis from similar pathologies is of paramount importance, due to its different strategy in treatment (Table 1). Differential diagnosis should mainly be made from De Quervain Syndrome (DQS)^[3]. Other pathologies such as scaphoid fractures, osteoarthritis of the first metacarpal joint, ganglion cysts, Wartenderg syndrome wrist ligament sprains, and muscle strains maybe also confused with IS and should be early diagnosed and properly treated^[1,6]. In DQS pain is localized distally to the dorsal interphalangeal joint of the thumb, in the first dorsal compartment that consists of the abductor pollicis longus and the extensor pollicis brevis. Finkelstein test in this case is considered pathognomonic^[21]. In IS, on the contrary, pain is identified 4-8 cm proximally to the radial styloid. The method of application of the test is important since it is a pathognomonic test guiding diagnosis. It is described as grasping the thumb within the fingers forming a fist and deviating the wrist in an ulnar direction. Still, the original description by Finkelstein reports that the patient's thumb is grasped with abduction of the wrist taking place in an ulnar direction, resulting in

Table 1 Differential diagnosis of radial wrist pain^[1,3,6]

Intersection syndrome
Tendonitis De Quervain
Scaphoid fractures
Osteoarthritis of the first metacarpal joint
Ganglion cysts
Wartenberg syndrome
Wrist ligament sprains
Muscle strains
Soft tissue neoplasms

intense pain over the styloid^[21]. Differentiating DQS from intersection syndrome is significant since in DQS earlier surgical intervention is recommended by some experts^[22].

IMAGING STUDIES

Although clinical diagnosis is usually sufficient, imaging studies offer a more certain diagnosis and clarify complicated injuries^[11].

Ultrasound imaging provides reliable and “first-line” diagnosis in the study of IS, while magnetic resonance imaging (MRI) studies are retrospective studies^[1]. It is important to note that the utility of the ultrasound in diagnosing IS is of value and even more important in research studies. Through ultrasound imaging, details in the anatomy of the region may be observed, that may explain symptoms or guide treatment. In the study by Draghi and Bortolotto^[8], valuable information was derived. The study can be considered of significant value since it took place over 5 years and included 1131 patients with hand and wrist pathology. It was reported that tendons may be coated in one sheath or individual sheaths and a second location of an intersection was underlined. This information may be beneficial in both research and clinical level. For instance, a more detailed anatomy or pathologic anatomy may elucidate the mechanics of injury and healing. It may also result in improved effectiveness in injection therapy, by targeting the intended site.

Clinical examination may be accompanied by axial MRI^[3]. de Lima *et al.*^[4], studied through MRI scans the anatomy of the forearm around the intersection area, before and after tenography. The authors of this study concluded that MRI may be a useful noninvasive method for the evaluation of wrist pain. In T2 weighted fat suppressed fast spin echo axial MRI, peritendinous and subcutaneous edema concentrically both proximally and distally of the intersection site) or even synovial effusion are depicted in the presence of intersection syndrome pathology^[6,7]. Lee *et al.*^[9], in a review of intersection injury studied through MRI, identified also tendinosis and subcutaneous and muscle edema as abnormalities related to this overuse syndrome.

Of note, although imaging studies may be useful in identifying and confirming IS, is reported that 70% of cases can be found through appropriate history

taking^[23].

TREATMENT

It is common ground that the fundamental element for the recuperation of an overuse injury is informing the patient of the steps he or she may follow to assist in healing. Patient education thus is important in IS and understanding of the mechanism of injury will aid in conceiving how to protect and progressively rehabilitate the wrist back to its normal daily activities^[24].

In the first phase, the proposed main line of action consists of rest, use of oral nonsteroidal anti-inflammatory medication, cryotherapy, elevation, and compression. Although inflammation is necessary for the proper cascade of healing of the site of injury, reduction to some extent of inflammation to result in the reduction of pain is necessary in order to eliminate disabling symptoms as soon as possible^[3]. The second phase of rehabilitation consists of the gradual restoration of function of the upper extremity to former daily activities. This phase lasts 4-6 wk and consists of progressive stretching and mobilization of relevant joints that is the wrist, elbow joint, metacarpophalangeal and phalangophalangeal joints and other structures such as musculature, tendons, and fascia. Strength training should be initiated carefully to avoid relapse of symptoms. The performance of daily life activities is a part of training, in order to reach full functional rehabilitation. The general rule of increasing parameters such as intensity, repetition, or distance per week, has been shown to be a beneficial rule of thumb for runners^[20].

Immobilization through splinting is proposed in the literature^[20]. Immobilization of the wrist as well as the thumb has been proposed, with a thumb spica splint, strapping or use of a cock up wire-splint^[3]. The anatomical position of immobilization is 20 degrees of extension of the wrist. The duration of immobilization in research studies extends from 2-3 wk^[20,23].

Persistence of symptoms after 2-3 wk, leads to the consideration of a second line of available treatment procedures available^[21]. A percentage of 60% has been reported to heal solely through conservative management^[18]. Corticosteroid injections may alleviate pain and reduce inflammation^[25]. Injections may be administered adjacent to the maximally tender areas solely, providing relief after 10 d^[3].

Resolving to surgical intervention is very effective but is offered only to patients not responding to conservative treatment. Operative management consists of Abductor Pollicis Longus (APL) and Extensor Pollicis Brevis (EPB) tenosynovectomy and fasciotomy, and debridement of the bursa so as to result in release compression at the crossover site^[17,18] while post-operatively immobility using plaster forearm splint is recommended for ten days. Return to full activity is permitted from at least 12 wk^[26].

Williams *et al.*^[27], described the decompression of the

muscle belly of the swollen by overuse muscles. They performed an incision at the site of maximum swelling, aiming at decompression of the extensors beneath. This incision is performed 3-4 cm proximal to the incision for De Quervain tenosynovitis. It may take place by local anesthesia, by bypassing superficial layers to reach the tendon and fascia of the APL and EPB. In 11 patients, mostly rowing athletes presenting with overuse syndrome of the extensors of the wrist, this technique was performed. Return to light training was achieved from the first day post-surgery and return to training 10 d later. No return of symptoms was reported even 4 mo following operation^[27].

Another therapeutic approach was proposed by Grundberg and Reagan^[5]. According to the authors pathology relates mainly to Extensor Carpi Radialis Brevis (ECRB) and Extensor Carpi Radialis Longus (ECRL) who are responsible for the more proximal than the De Quervain localization of pain. This decompression of the second extensor compartment is thought to resolve symptoms of the syndrome. This technique was performed to 13 patients with IS of a duration from 4 mo to 5 years, where conservative treatment had failed. In two patients a surgical approach was implemented more proximally to the tendon of the carpal extensors which rendered unsatisfactory results. In line incision of the carpal extensors was performed with a direction centrally towards the area of the marked edema. Release of ECRL and ECRB within the second dorsal compartment after dissecting the deep fascia achieved reduction of symptoms in all patients ten months on average, postoperatively. All patients returned to their former employment^[5].

DISCUSSION

Up to this day, there is a debate whether IS is a tendinosis, thus a chronic tendon degeneration with the absence of inflammation or a peritenosynovitis, involving an inflammatory process across the tendon sheaths^[28,29]. Furthermore, as reported above the site of injury in IS is also debatable, since it may occur at two different intersections of the second compartment with the abductor extensor longus and extensor pollicis brevis or more distally with the extensor pollicis longus alone.

The establishment of diagnosis of this pathology is based mainly on thorough clinical examination and should be achieved early in order to avoid functional impairment of the affected hand and devastating consequences for patients and especially these interfering with athletic activity. Differential diagnosis includes several nosologic entities which provoke wrist pain and mainly De Quervain Syndrome^[1,3,26].

Treatment includes mainly conservative therapeutic strategies such as rest, immobilization with a thumb spica splint, analgetic and non-steroid anti-inflammatory drugs (NSAIDS) and after 2-3 wk progressive stretching and muscle strengthening. Injection therapy using

drugs such as using 2 mL of 1% of lidocaine with betamethasone, is another conservative therapeutic option which is proposed when symptoms persist more than few weeks of immobilization^[25]. Still, major adverse events that may take place and represent a percentage of 5,8%, have to be discussed with the patient. These range from a simple ecchymosis which may occur to as much as a devastating tendon rupture^[25].

As conservative treatment is generally an efficient therapeutic approach for IS, surgical management is warranted only for refractory cases and is followed with good results^[5,17,18,27].

CONCLUSION

Intersection syndrome is not a clearly understudied syndrome. The etiology, site of injury, histologic underlying changes are still debatable. Moreover, the extent of the utility of imaging studies in diagnosis is still not entirely clear. Adding to the necessity of further elucidating all aspects of the syndrome, every possible way of studying the syndrome is proposed. The utility of imaging in research as a means of studying histology and anatomy is supported as well as the need to conduct studies with larger samples in order to study the injury in depth.

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Retrospective Study

Ponseti method treatment of neglected idiopathic clubfoot: Preliminary results of a multi-center study in Nigeria

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Informed consent statement: Patients were not required to give informed consent to the study because the analysis used anonymous clinical data from the International Clubfoot Registry. Patients agreed to be a part of the registry at the commencement of treatment by written consent.

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Abstract

AIM

To evaluate the effectiveness of the Ponseti method for initial correction of neglected clubfoot cases in multiple centers throughout Nigeria.

METHODS

Patient charts were reviewed through the International Clubfoot Registry for 12 different Ponseti clubfoot treatment centers and 328 clubfeet (225 patients) met inclusion criteria. All patients were treated by the method described by Ponseti including manipulation and casting with percutaneous Achilles tenotomy as needed.

RESULTS

A painless plantigrade foot was obtained in 255 feet (78%) without the need for extensive soft tissue release and/or bony procedures.

CONCLUSION

We conclude that the Ponseti method is a safe, effective and low-cost treatment for initial correction of neglected idiopathic clubfoot presenting after walking age. Long-term follow-up will be required to assess outcomes.

Key words: Ponseti method; Neglected clubfoot; Nigeria; Walking age

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Core tip: This is a retrospective study to evaluate the efficacy of the Ponseti method for initial correction of untreated, idiopathic clubfoot in patients above one year of age. The rate of initial correction to a painless, plantigrade foot without the need for soft tissue release was 78% in 255 evaluated clubfeet from 12 treatment centers in Nigeria. The Ponseti method, a non-operative treatment method involving serial manipulation and casting, is useful and effective for initial correction of clubfoot, even after walking age.

Adegbehingbe OO, Adetiloye AJ, Adewole L, Ajodo DU, Bello N, Esan O, Hoover AC, Ior J, Lasebikan O, Ojo O, Olasinde A, Songden D, Morcuende JA. Ponseti method treatment of neglected idiopathic clubfoot: Preliminary results of a multi-center study in Nigeria. *World J Orthop* 2017; 8(8): 624-630 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v8/i8/624.htm> DOI: <http://dx.doi.org/10.5312/wjo.v8.i8.624>

INTRODUCTION

Idiopathic clubfoot is the most common musculoskeletal congenital birth defect, affecting between 1 and 7 births in every 1000^[1]. Left untreated, clubfoot may lead to pain, disability, discrimination, and hardship throughout the person's life. This is especially a problem in developing countries like Nigeria where 70% of the

population lives below the poverty line and has limited access to treatment. Although Nigeria has around half the population of the United States at about 180 million, it is estimated that the prevalence of clubfoot is at least three to five times higher than in the United States. This high prevalence is mainly a result of the number of people living with neglected clubfoot, defined as clubfoot that has not been treated before walking age^[2,3].

For many years in Nigeria and around the world, soft tissue release or extensive bony surgery were seen as the only options for the full correction of clubfoot. In the past two decades, the minimally invasive Ponseti method has been proven and accepted as the worldwide gold standard for treatment of clubfoot based on its success in both the short term and long term^[4]. Introduced in Nigeria in 2009, the Ponseti method is a safe, effective, and economical option for many patients who cannot afford an extensive surgery. The method involves skilled serial manipulation and plaster casting as well as a percutaneous Achilles tenotomy (PAT) to completely correct the deformity. After the correction is complete, the child wears a foot abduction brace at night for a few years to prevent relapse^[5-7].

There are few studies on the effectiveness of the Ponseti method for patients over age 1, but the early evidence has been promising. Studies in Brazil, Nepal, India and Ethiopia reported that use of the Ponseti method allowed for avoidance of soft tissue release in 66%-92% of cases above one year of age^[8-16].

The purpose of this study was to evaluate the effectiveness of the Ponseti method for initial correction of neglected clubfoot cases in multiple centers throughout Nigeria.

MATERIALS AND METHODS

The accepted definition of neglected clubfoot is true idiopathic clubfoot that has not been treated before walking age. In this study, age one will be used as representative of walking age. Through July 2015, 1137 clubfoot cases from 2010-2015 were recorded from Ponseti treatment centers in Nigeria into the International Clubfoot Registry with patient permission. Patient charts were reviewed through the registry. Two hundred and twenty-five patients (328 clubfeet) from 12 different centers (Figure 1) met inclusion criteria and are profiled in Table 1. Patients were excluded if they were younger than 1 year of age, had non-idiopathic clubfoot (syndromic, neuromuscular, etc.) or had other treatment prior to Ponseti method.

Treatment at all 12 centers, including casting and percutaneous Achilles tenotomy as necessary, was performed by orthopaedic surgeons who were properly trained in the technique according to Ponseti^[5-7]. Casts were changed at intervals of 7-10 d if possible but up to every 14 d depending on the ability of the patient to reach the clinic and pay for the treatment. All patients were treated on an outpatient basis although two of the twelve centers, including 18 total patients, performed

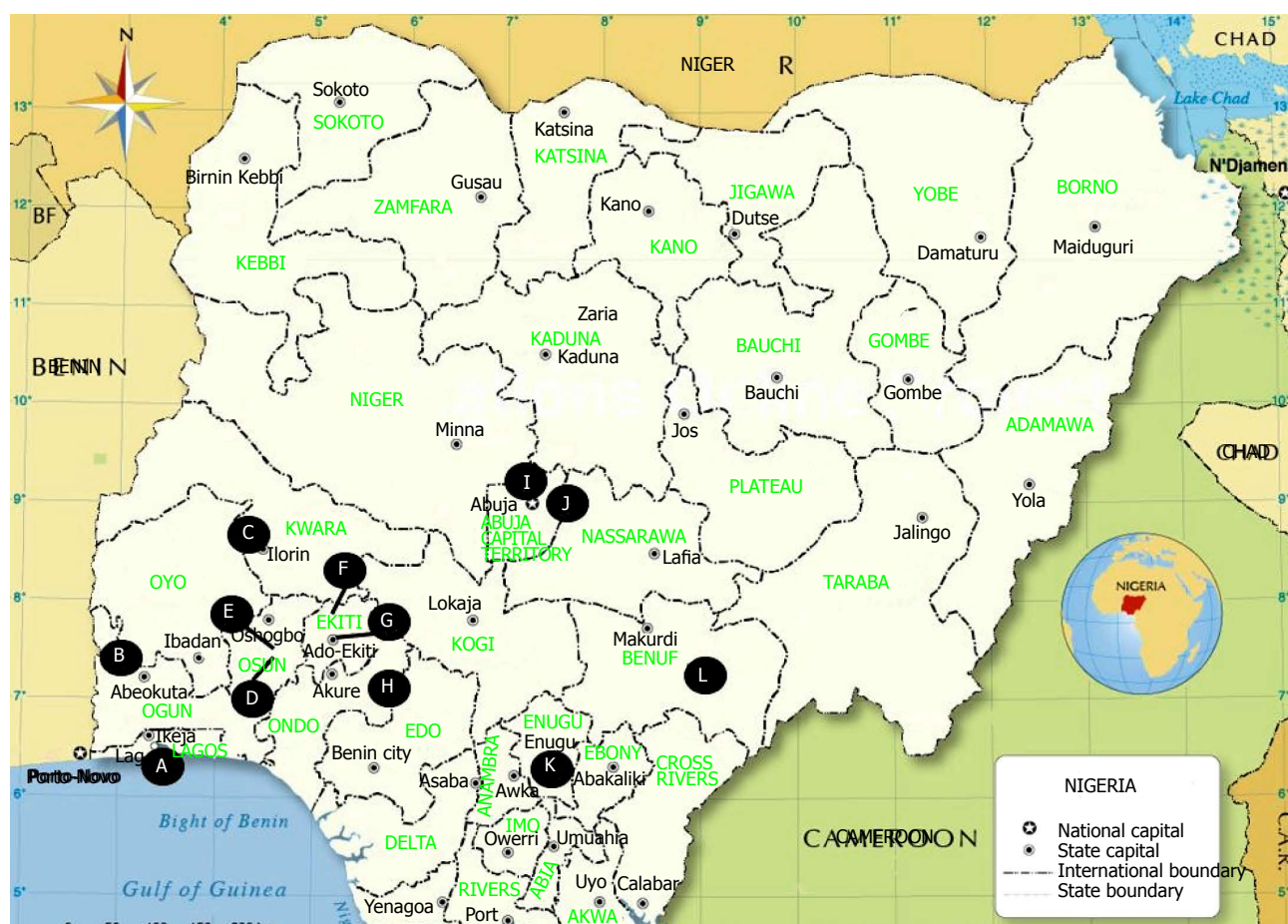


Figure 1 Map of clubfoot clinic sites. A: LASUCOM; B: FMC Abeokuta; C: University of Ilorin; D: Obafemi Awolowo University; E: Wesley Guild Hospital Ilesha; F: FMC Ido-Ekiti; G: Ekiti St Teaching Hospital; H: FMC Owo; I: Gwarinpa GH; J: FMC Keffi; K: NOH Enugu; L: NKST-Mkar, Benue.

Table 1 Phenotypic characteristics *n* (%)

	Cases
Female	94 (42)
Male	131 (58)
Bilateral	103 (46)
Right	66 (29)
Left	56 (25)
Age 1-2 yr	147 (65)
Age 3-9 yr	59 (26)
Age ≥ 10 yr	19 (9)

tenotomies in the operating theatre for optimal sterility. Although tendon transfer can be considered part of the Ponseti protocol, one of the main objectives of this study is to show that neglected clubfoot can be corrected non-operatively as that is most beneficial in the low resource setting. Therefore in this study, tendon transfer will be considered failure in treatment along with tendoachilles lengthening and major soft tissue release.

After completion of serial casting, correction was maintained with a foot abduction brace at night or in rare cases when braces were not available, with encouragement of active play (walking, running, etc.). Abduction braces were generally crafted by each hospital's orthotics department or local cobblers working

with the orthopaedic surgeons.

In the newborn population, Pirani and Dimeglio scoring systems are generally used to assess the severity and characteristics of a clubfoot. These systems have been validated and are useful for comparing the quality of correction^[17,18]. However, these have not been validated for the neglected population and no system exists yet for the qualification of neglected clubfoot^[19].

RESULTS

The study population consisted of 225 patients, 131 (58.2%) were male, and the clubfoot was bilateral in 103 cases (46%). One hundred and forty-seven patients were age 1 or 2, 59 were between the ages of 3 and 9, and 19 patients were age 10 to 16.

Of 328 neglected clubfeet studied, 255 feet (78%) achieved initial correction, a completely plantigrade foot, without soft tissue release or other surgical intervention besides PAT. Of the 73 other feet, 47 were lost to follow up mid-treatment and 26 of the feet were converted to Achilles tendon lengthening, tendon transfer procedures, or major soft tissue release.

A profile of the total number of casts required for complete correction and the PAT rates based on age group is shown in Table 2. A distribution of the number

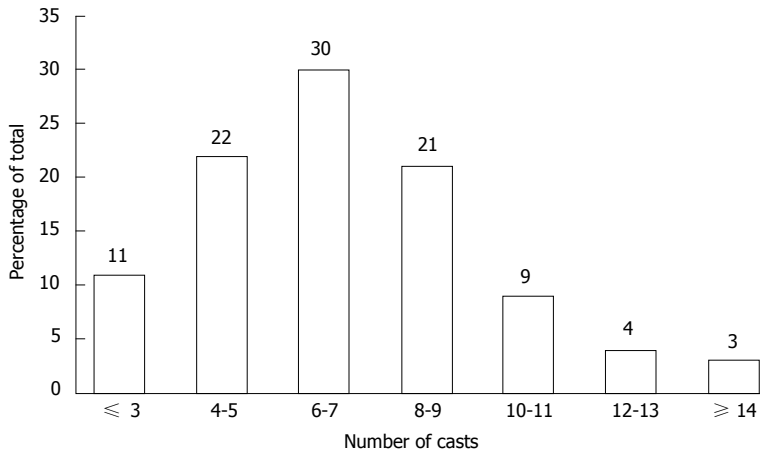


Figure 2 Number of casts required for correction.

Table 2 Number of casts and tenotomy rate

	Total	Age 1-2 yr	Age 3-9 yr	Age 10-16 yr
Mean casts ¹ , <i>n</i> (range)	6.84 (3-20)	6.71 (3-20)	7.03 (4-17)	7.43 (4-13)
Tenotomy rate	51%	42%	53%	60%

¹Between groups ANOVA *P*-value = 0.78.

of casts required across all age groups is shown in Figure 2. The average number of casts necessary for correction was 6.84, ranging from 6.71 casts/foot for 1 and 2 year olds up to 7.43 casts/foot for those above age 10. Analysis of variance between the groups shows no statistically significant difference ($P = 0.78$). The overall rate of percutaneous Achilles tenotomy was 51% and also tended to increase with patient age from 42% in the youngest age group to 60% in the oldest. There were no failures of PAT's reported.

DISCUSSION

Neglected clubfoot is a serious problem in developing nations where a significant number of children born with the deformity do not receive immediate treatment. It is common for parents to delay treatment due to cost, lack of transportation or limited availability of proper care. Frequently, children do not present until around the start of school age at 4 or 5 because of increased interaction with peers and social pressures to fit in. Neglected clubfoot can cause significant physical, psychological and financial burden to the child and the family. Adults with untreated clubfoot may experience significant pain and disability, be unable to work, and have difficulty performing daily activities of living.

Historically, neglected clubfoot has been treated with bony surgery and extensive soft tissue release. These techniques are difficult, costly, have substantial complication rates, and they are rarely feasible in the healthcare settings of developing nations^[20-23].

Our study has shown that the Ponseti method is

effective in the initial correction of neglected clubfoot and reduction of the need for surgical treatment beyond percutaneous tenotomy. Its suitability at the clinical level is imperative for use in developing countries like Nigeria, where operating room access comes at a premium. Our results are similar to multiple recent studies on Ponseti treatment of neglected clubfoot cases, shown in Table 3.

Ponseti *et al.*^[5] described successful results from Brazil after Ponseti treatment in 17 children (24 feet) with an average age at presentation of 3.9 (1.2-9.0). A full correction was achieved in 16 feet (67%) without the need for extensive surgery and it was found that those who eventually needed surgery ended up with a lesser surgical intervention. Six of the patients had recurrence, and the best results were achieved in the youngest group.

In Nepal, Ponseti *et al.*^[6] reported the use of Ponseti treatment in neglected cases between the age of 1 and 6. In 260 feet, 83% were able to avoid any surgery besides PAT. Similar to our study, with a broader range of ages and larger study group, they found a wider range of casts were necessary to achieve full correction.

Spiegel *et al.*^[9] in India had 37 neglected clubfoot patients (55 clubfeet) with a mean age of presentation of 2 (1-3) years. After a Ponseti trial, 4 patients (6 feet) were considered unfit for Ponseti treatment and had a posteromedial release, 4 patients (4 feet) relapsed and had tibialis tendon transfer and 3 patients (4 feet) required tendoachilles lengthening to obtain adequate dorsiflexion.

In Ethiopia, Khan *et al.*^[11] found that in 22 neglected clubfoot patients (32 feet), an open tendoachilles lengthening was required for 5 patients (7 feet) plus posterior capsulotomy in 3 additional patients (4 feet). Correction was achieved for the remaining 14 patients (21 feet) with the Ponseti method and PAT alone.

In our study, 78% of 328 feet achieved correction without major surgery. Some factors, such as time between casts, were variable between the 12 different treatment centers because of the socioeconomic differences between the regions of Nigeria. In a survey of

Table 3 Published results on correction of neglected clubfoot

	Brazil, 2007	Nepal, 2009	India, 2012	Ethiopia, 2014	Present study
Total number of feet	24	260	55	32	328
M/F	12/5	120/51	7/30	5/17	131/94
Mean casts, <i>n</i> (range)	9 (7-12)	7 (4-14)	10 (6-12)	8 (6-10)	7 (3-20)
Successful correction without surgery	67%	83%	71%	66%	78%

the providers at each center, reportedly patients who were wealthier or in more urban areas were more likely to have casts changed slightly more frequently, 7-8 d as opposed to 13-14. PAT's were performed under local anesthesia in clinics at 10 sites and in the operating theatre at 2 sites (18 study patients) for better infection control and sterile instruments.

If the number of casts required for correction can serve as a proxy for the severity of a clubfoot, neglected clubfoot can be described simply as a more severe form of idiopathic clubfoot in a newborn. The average number of casts required in newborns is around 5 with a correction rate around 90%^[4]. In our study and review of the literature, casts required for neglected cases is between 7 and 10 with successful correction rates from 66%-83%. The Ponseti method is nearly as successful on neglected clubfoot as in newborns at preventing the need for surgical intervention.

The phenotypic characteristics for cases in our study were similar to the reported rates of incidence of congenital idiopathic clubfoot in the literature^[24-27]. Fifty-eight percent of patients in our study population were male, consistent with the evidence that males are twice as likely to be affected. Also, in concordance with the evidence that half of cases occur bilaterally, 46% of our cases were bilateral and 54% were unilateral. This is significant because there has not been profound gender or laterality bias in presentation of neglected cases. Therefore, these factors do not seem to affect parents' willingness to seek treatment for their children before age 1.

One intriguing finding in our study is that the percutaneous Achilles tenotomy rate seems to be lower than in much of the literature^[5-11]. There are a few unique factors that could be causing this finding. The first is that there was considerable variability in rate of tenotomy between different centers. Costs for sterile equipment, local anesthetic and time required may be causing some providers to increase the number of casts to achieve necessary dorsiflexion rather than performing a PAT. It is also possible that some of the cases treated were actually positional equinovarus deformity rather than true talipes equinovarus, and did not require tenotomy. General guidelines for the Ponseti method recommend that a clubfoot achieve 15° of dorsiflexion to be considered corrected^[22]. More research into the tenotomy rate for neglected clubfoot worldwide and for all idiopathic clubfoot in Nigeria would be encouraged.

Our study has some potential limitations. During the course of treatment, 47 patients were lost to follow

up. In the setting of a developing country, patients are often lost to follow-up because of socioeconomic factors such as costs, transportation, and lack of social support and behavioral factors such as feeling improved function mid-treatment and knowledge deficit about duration of treatment^[24]. Data collection was variable between centers so 32 neglected clubfoot patients had to be excluded from the initial study population because there was not enough treatment data. If more data could be recorded, research into the feasibility of Pirani and Dimeglio scoring for neglected clubfoot would be very helpful and could aid providers in guiding their manipulation and casting to each individual. The current algorithm for Ponseti treatment of neglected clubfoot is provided in Figure 3.

In conclusion, this study has shown that the Ponseti method can be effectively used to correct neglected clubfoot in children older than walking age. If the method is performed properly, it will significantly reduce the need for bony surgery or major soft tissue release.

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This study was made possible by the creation of the Nigerian Sustainable Clubfoot Childcare Program (NS CCP), a nonprofit organization established to be a leader and model for clubfoot treatment throughout Africa. The NSCCP combines physicians, parents, and clubfoot advocates in efforts to increase public awareness, especially among local healthcare workers such as midwives. It also helps organize Ponseti trainings for orthopaedic surgeons and collaboration between those who are treating clubfoot frequently. It was the collaboration of the physicians who are part of the NSCCP that led this study and shows the benefit the Ponseti method has on neglected clubfoot in Nigeria.

COMMENTS

Background

Clubfoot is the most common musculoskeletal birth defect and left untreated, can result in lifelong disability and hardship. The Ponseti method involving serial manipulation and casting has become the gold standard in treatment of clubfoot. In low resource and developing countries, neglected clubfoot, or clubfoot that is untreated by one year of age, is a significant problem because of limited access to healthcare. In this study, the authors evaluated the efficacy of the Ponseti method in treating neglected clubfoot in 12 centers in Nigeria.

Research frontiers

Currently, there is very little literature on the effectiveness of the Ponseti method in clubfoot patients over age one. The current studies are on small populations

Algorithm No. 3
Management of idiopathic clubfoot
Patient walking

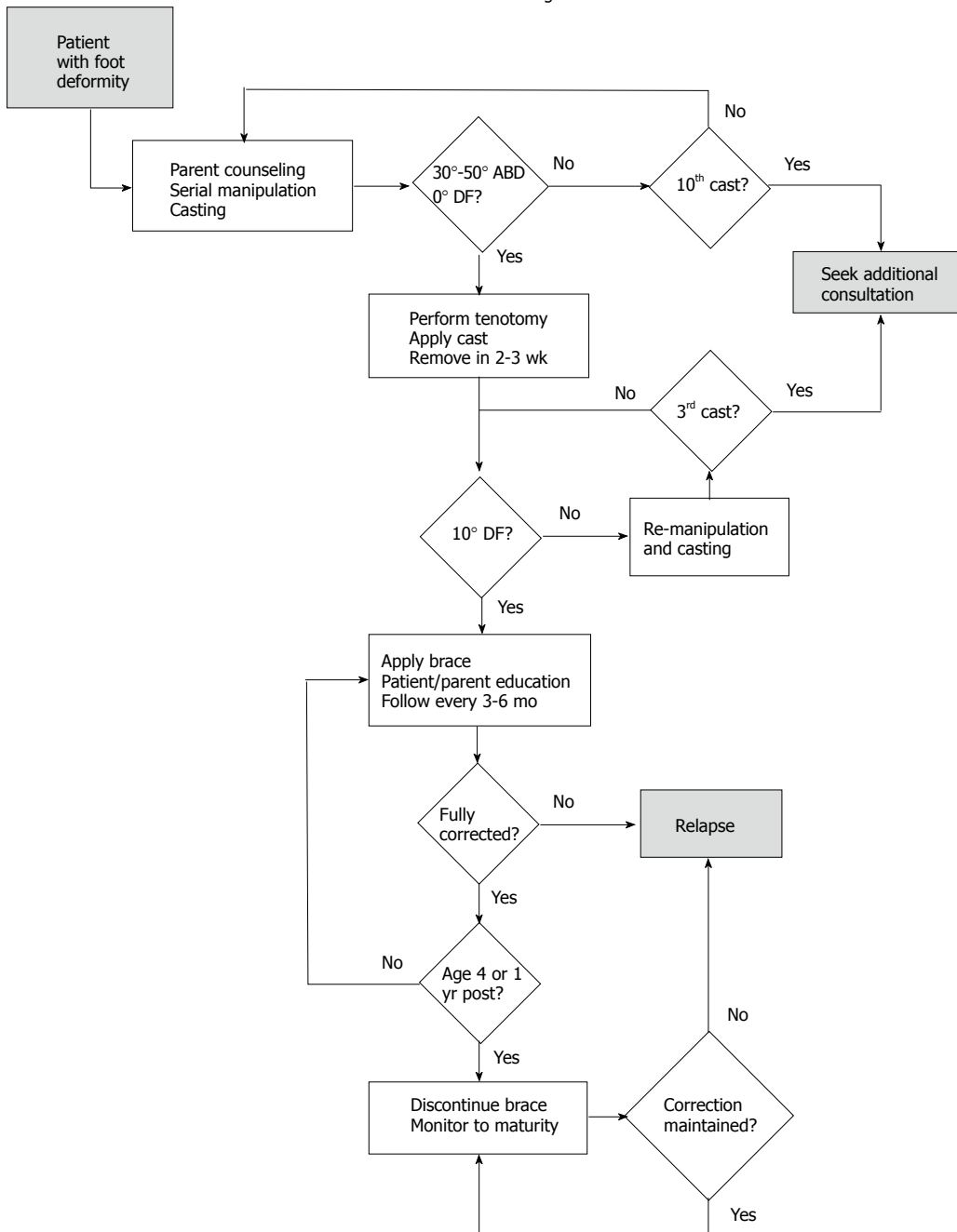


Figure 3 Neglected clubfoot treatment algorithm. Adapted form Ref. [29].

but have shown significant success.

Innovations and breakthroughs

In this study, the Ponseti method was successful in the initial correction of 78% of neglected clubfeet. These results are in concurrence with previous, smaller studies which showed similar correction rates.

Applications

This study suggests that providers throughout the world who are treating neglected clubfoot should begin with the Ponseti method as it can be performed at low cost and is highly effective.

Terminology

PAT: Percutaneous achilles tenotomy - minimally invasive procedure involving

the nicking of the heel cord in order to achieve maximal stretching in the final phase of treatment.

Peer-review

The paper is interesting and emphasizing the statement that Ponseti method can be effectively used to correct neglected clubfoot in children older than walking age, and significantly reduce the need for bony surgery or major soft tissue release.

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Observational Study

Functional outcomes of traumatic and non-traumatic rotator cuff tears after arthroscopic repair

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Abstract

AIM

To compare the functional outcomes of traumatic and non-traumatic rotator cuff tears after arthroscopic repair.

METHODS

Eighty-seven patients with rotator cuff tears following arthroscopic treatment were divided into traumatic and non-traumatic tear groups. Postoperative muscle strength and outcomes using the modified University of California, Los Angeles score were evaluated. Sex, age, affected limb and dominant limb were correlated between groups. Muscle strength of the repaired and unaffected shoulders was compared. Rotator cuff injury size was measured.

RESULTS

Of the 87 patients who underwent rotator cuff repairs, 35 had traumatic tears and 52 had non-traumatic tears. In patients with non-traumatic tears, the average age was 59 years, 74.5% were female, 96.1% were right-hand dominant and 92.3% had their dominant shoulder affected. Patients with traumatic tears were 59.5 years

old on average, 51.4% were female, 91.4% were right-hand dominant and 88.5% had their dominant shoulder affected. No difference existed in the mean modified University of California, Los Angeles score between patients with traumatic tears (33.7) compared with those with non-traumatic tears (32.8). No strength differences were observed between groups: The strength difference between the non-affected and affected sides was 1.21 kg in the non-traumatic group and 1.39 kg in the traumatic group ($P = 0.576$), while the strength ratio between the non-affected/affected sides was 0.805 in the non-traumatic group and 0.729 in the traumatic group ($P = 0.224$).

CONCLUSION

The functional results of traumatic rotator cuff repairs are similar to non-traumatic tears. Both outcomes are satisfactory.

Key words: Rotator cuff; Shoulder pain; Arthroscopy; Tendon injuries; Orthopedics

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Core tip: The causes of rotator cuff tears are multifactorial. It is believed that degeneration is essential, and most tears are slow and progressive. In contrast, acute tears can occur after trauma. Acute tears generally have better functional and pain outcomes compared with chronic injuries. The aim of this study is to compare shoulder functional outcomes after arthroscopic rotator cuff repair of traumatic and non-traumatic tears. Outcomes will be evaluated using the modified University of California, Los Angeles score and muscle strength measurements.

Abechain JJK, Godinho GG, Matsunaga FT, Netto NA, Daou JP, Tamaoki MJS. Functional outcomes of traumatic and non-traumatic rotator cuff tears after arthroscopic repair. *World J Orthop* 2017; 8(8): 631-637 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v8/i8/631.htm> DOI: <http://dx.doi.org/10.5312/wjo.v8.i8.631>

INTRODUCTION

Rotator cuff injuries are very common, ranging from 5%-39%. They are the leading cause of shoulder pain, and have a high prevalence in the aging population^[1]. They can cause intense shoulder pain, functional limitation and decreased quality of life^[2-7]. It is extremely important to understand these injuries to treat them appropriately, as it is likely that every physician, not just orthopedic surgeons, will encounter this pathology.

The rotator cuff is a group of muscles that cover the humeral head and plays an important role in the strength, mobility and stability of the shoulder by fixing the humeral head to the glenoid. The rotator cuff consists of four muscles: Subscapularis, supraspinatus,

infraspinatus and teres minor. The tendons of these muscles merge with the joint capsule. Around the shoulder joint and between the tendons of the rotator cuff muscles and the fibrous joint capsule, bursa reduces the friction of the tendons that pass over bone or other areas of resistance^[8].

In general, the treatment for rotator cuff tears should be clinical, even in cases in which anatomic changes are also present^[9]. However, in cases of rotator cuff failures, surgical treatment is indicated^[4]. Rotator cuff repairs can be performed through either arthroscopic or open approaches. Arthroscopic surgery is performed through micro incisions and preserves the deltoid muscle insertion, theoretically permitting early rehabilitation and a lower risk of iatrogenic injuries or complications from deltoid healing.

The causes of rotator cuff tears are multifactorial. However, it is believed that degeneration is an essential factor, as this leads to a high rate of non-healing or failures, which range from 10%-94%^[10-17]. In most cases, rotator cuff tears are slow and progressive injuries, occurring after a relatively long period of symptoms. However, acute tears can also occur secondary to trauma. This mechanism has been found to have better functional and pain outcomes than chronic injuries.

We therefore decided to compare functional outcomes after arthroscopic rotator cuff repairs of those patients who sustained traumatic rotator cuff tears, and those without traumatic etiologies. This may help us understand the post-surgical function of these patients, and support clinical decision making.

MATERIALS AND METHODS

This is a retrospective study of 87 adult patients with rotator cuff injuries treated arthroscopically at the Hospital Ortopédico de Belo Horizonte. Most of them were operated from June to December 2014, and the others were retrospectively selected by medical records. All patients were informed about the objectives of this protocol and signed a consent form agreeing to participate in the study. The study was approved by the National Ethics Committee on Research.

The average patient follow-up was 43 mo (range 24-72 mo). Lesions were characterized clinically and with magnetic resonance imaging, and the criteria for surgery was determined after a discussion meeting.

The traumatic rotator cuff tear group was defined^[18] by trauma followed by acute shoulder pain associated with impaired active range of motion of the affected limb. This trauma can be a cause of a medial rotation or lateral force with the arm adducted or abducted, a ventral, medial or caudal passive draw force, an axial compressive force toward the cranial and ventral or ventromedial direction or secondary to a shoulder dislocation. It was expected that the patient did not have any pain before the trauma. In all cases, fractures were excluded using anteroposterior, lateral and axillary radiographs of the affected shoulder. In this group,

surgeries were performed within six months after the traumatic event.

For the non-traumatic rotator cuff injury group, inclusion criteria were a chronic history of shoulder pain with pre-existing limited shoulder function. Acromioclavicular osteoarthritis and osteophytes of the acromion are also commonly observed.

Exclusion criteria included: Bilateral lesions, previous surgery in the affected limb, patients that required other upper extremity surgical procedures after the rotator cuff repair and any condition that would interfere with the evaluation of long term outcomes, such as rheumatoid arthritis or fractures. Patient demographics of interest included sex, age, affected limb, dominant limb and mechanism of injury (traumatic or non-traumatic).

All patients were evaluated 24 mo after surgery, since most cases of re-rupture occur before two years after surgery^[19-21]. In patients who were selected retrospectively, we used the evaluations performed within 24 mo. The primary outcome was modified University of California, Los Angeles (UCLA) score validated for the Portuguese language, which takes into account pain, function, range of motion, strength and patient satisfaction^[22,23].

The modified UCLA scale is scored out of a total of 35 points. Subsections include: Pain (10 points), function (10 points), active forward flexion range of motion (5 points), a manual strength test for forward flexion (5 points) and patient satisfaction (5 points). Outcomes according to this scale are as follows: 34-35 points correspond to excellent results, 28-33 good, 21-27 satisfactory and 0-20 poor^[23]. No minimum clinically important difference has been reported using this scale^[24]. The modified UCLA scale can be easily applied, and allows for effective clinical tracking. It is also one of the only patient satisfaction scales that are validated for the Portuguese language^[22].

Arm strength was measured with the patient positioned in orthostasis, with the upper limb in 90 degrees of elevation and angled 30 degrees anteriorly, corresponding to the abduction axis in the scapular plane^[25]. We used a dynamometer that consisted of a household scale with a maximum capacity of 20 kg (Performance Plus, Performance Plus Ind. E Com. Ltda., Rio de Janeiro - RJ, Brazil). One end of the dynamometer was fixed to a fabric strap wrapped around the distal end of the forearm that was maintained in full pronation^[26]. The other end of the dynamometer was secured to the scale's spring and attached to a nylon rope whose length reached the foot of the patient. The other end of the rope was secured with a handle attached to the patient's footwear. This setup allowed for force measurements with a fixed point (foot). The patient was asked to exert the maximum possible strength during upper limb elevation for 5 s. The final reading at the end of this period was used to represent limb strength^[27]. We avoided placing the bracelet on the wrist or hand, where local muscle activity could

confound our measurements. Avoiding this positioning also helped to keep the patient's trunk upright, avoiding compensation with lateral tilt. Muscle strength of the injured shoulder was compared with the unaffected side, and correlated with rotator cuff injury size.

Surgical technique

All patients received general anesthesia and a brachial plexus block. They were positioned in the lateral decubitus position with a vertical and longitudinal traction of 5 kg fixed to the affected arm. The arthroscope was introduced through a posterior portal positioned 2 cm medial and 2 cm below the posterolateral edge of the acromion. The joint was evaluated for degenerative or inflammatory changes, which were treated with synovectomy and debridement through an anterior portal along the top edge of the subscapularis muscle with a shaver blade. When the rotator cuff tendon injury was observed, a monofilament was introduced to demarcate the injury site, making it easy to locate during subacromial view.

Subacromial view was performed through the same posterior portal. The arthroscope was introduced into the subacromial space and a bursectomy was performed with the shaver blade introduced through a lateral portal.

The rotator cuff injury was repaired using 5 mm titanium suture anchors placed into the anatomic neck of the humerus. It was made single row repair with Revo knots. When the subacromial space was found to be pathologically decreased, an acromioplasty was performed as well. All arthroscopic portals were closed using monofilament suture.

Patients were immobilized postoperatively in a Velpeau sling (Mercur, Santa Cruz do Sul - RS, Brazil) for 6 wk. Sutures were removed 10-14 d after surgery. Patients were encouraged to start pendulous movements and elbow, wrist and hand range of motion immediately after surgery. Active motion was only permitted 6 wk after surgery, following evidence of restored strength and proprioception. It was used the same physical therapy protocol in both groups.

Statistical analysis

The statistical review of the study was performed by a biomedical statistician. A *P*-value < 0.05 was considered significant. Our confidence interval was 95%. A paired Student's *t*-test was used to compare outcomes between affected and unaffected shoulders. This test was selected because the same subject contributes to the experimental and control sample.

We used an analysis of variance (ANOVA) to compare subjects with and without a traumatic injury to the strength ratio of the affected and unaffected shoulder. The ANOVA was also to compare mean age, UCLA-modified score and strength differences between the affected and unaffected shoulders. The two-proportion equality test (χ^2 test) was used to compare the sex distribution of traumatic vs non-traumatic rotator cuff

Table 1 Sex distribution of patients with traumatic *vs* non-traumatic rotator cuff tears *n* (%)

Trauma	No	Yes	<i>P</i> -value
Female	38 (74.5)	18 (51.4)	0.027
Male	13 (25.5)	17 (48.6)	

Table 2 Average ages of patients with traumatic *vs* non-traumatic rotator cuff tears

Age	Trauma	
	No	Yes
Mean	59	59.5
Median	60	62
Standard deviation	8.4	9.7
Coefficient of variation	14%	16%
Minimum	40	42
Maximum	75	76
Patients	51	35
Confidence interval	2.3	3.2
<i>P</i> -value	0.799	

tears.

RESULTS

The clinical and functional data of 87 patients who underwent a rotator cuff repair were analyzed. Thirty-five had traumatic tears and 52 had non-traumatic tears. Both groups were treated using the same surgical technique. The mean follow-up was 43 mo (24–72 mo). Women composed 74.5% of non-traumatic rotator cuff tears, compared with 51.4% of traumatic tears. This difference in sex distribution was significant ($P < 0.05$, Table 1).

The average age of the non-traumatic group was 59 years, compared with 59.5 years in the traumatic group (Table 2). In the traumatic group, 91.4% were right-hand dominant and 88.5% had their dominant limb affected. In the non-traumatic group, 96.1% were right-hand dominant and 92.3% had their dominant limb affected. There was no difference in mean modified UCLA score between the non-traumatic (33.7) and the traumatic (32.8) groups (Table 3). The strength difference between the non-affected and affected sides was 1.21 kg in the non-traumatic group and 1.39 kg in the traumatic group ($P = 0.576$, Table 4).

There was no difference in the affected/non-affected strength ratio, which was 0.805 in the non-traumatic group and 0.729 in the traumatic group (Table 5). Significant differences were observed in the mean strength of the affected shoulder after surgery, which was 4.76 kg compared with 6.04 kg in the uninjured shoulder (Table 6). Tear size was 2.49 cm on average. It was 2.254 cm (range 1.0–5.4 cm) in the non-traumatic group and 2.84 cm (range 1.0–5.2 cm) in the traumatic group.

DISCUSSION

Rotator cuff injuries are multifactorial, and can include

Table 3 Modified University of California, Los Angeles scores of patients with traumatic *vs* non-traumatic rotator cuff tears

UCLA	Trauma	
	No	Yes
Mean	33.7	32.8
Median	35	35
Standard deviation	3.9	4.5
Coefficient of variation	12%	14%
Minimum	12	17
Maximum	35	35
Patients	51	35
Confidence interval	1.1	1.5
<i>P</i> -value	0.337	

UCLA: University of California, Los Angeles.

Table 4 Strength ratios between unaffected-affected shoulders of patients with traumatic *vs* non-traumatic rotator cuff tears

Unaffected-affected	Trauma	
	No	Yes
Mean	1.21	1.39
Median	1	1
Standard deviation	1.42	1.49
Coefficient of variation	117%	107%
Minimum	-1.5	-0.5
Maximum	6	4.5
Patients	51	35
Confidence interval	0.39	0.49
<i>P</i> -value	0.576	

degeneration because of age and microtrauma. Other factors that can increase the likelihood of a rotator cuff tear include smoking, hypercholesterolemia and genetics^[28]. The pathophysiology of rotator cuff tears is more complex than previously believed. The mechanisms behind rotator cuff injury and healing have a direct impact on treatment and recovery.

One common mechanism of rotator cuff injury is direct trauma to the tendon. Another mechanism is gradual tendon degeneration with age, predisposing the rotator cuff to tears. A widely held theory regarding rotator cuff injuries is the vascular theory, in which lesions occur because of hypovascularization near the rotator cuff's insertion on the humerus. In general, the injury process is of a multifactorial origin^[29].

Of the various factors that contribute to rotator cuff tears, such as trauma, subacromial impingement and hypovascularization, the most important is the aging process^[30]. Aging is a major prognostic indicator of tendon degeneration^[31]. The vast majority of rotator cuff ruptures occur in middle-aged and older patients^[32,33]. Previous studies have shown that the prevalence of rotator cuff injuries increases with age, reaching 50% by the 8th decade of life^[31].

Clinically, it is difficult to differentiate between patients whose rotator cuff injuries originate traumatically from those that have some degenerative component, as there is no way to know what degree of tendon degeneration occurred prior to the inciting

Table 5 Affected/unaffected shoulder strength ratio between patients with traumatic and non-traumatic rotator cuff tears

Strength ratio	Trauma	
	No	Yes
Mean	0.805	0.729
Median	0.833	0.857
Standard deviation	0.257	0.32
Coefficient of variation	32%	44%
Minimum	0.143	0
Maximum	1.6	1.083
Patients	51	35
Confidence interval	0.071	0.106
P-value	0.224	

trauma. This is especially important as a significant part of the population has some degree of asymptomatic tendon degeneration^[3]. Several authors^[18,34-36] proposed methods to differentiate between these two types of tears. However, there remains no established protocol. Therefore, because of the difficulty in differentiating between these two groups, we focused our analysis purely on those lesions that were diagnosed following trauma, rather than were determined to be of a purely traumatic origin. This may also provide greater clinical applicability to our findings.

In this study, the average age of the traumatic group was similar to the non-traumatic group. In the literature^[37-39] there is greater age heterogeneity in studies that identify trauma as a causal factor in rotator cuff injuries (mean age 34.2-56.1 years). This may be because of the variability in the selection criteria for assigning patients to a "purely traumatic tear" group. Studies that examine degenerative injuries have greater homogeneity (mean age 54.1-62.6 years).

In our study, most patients with degenerative tears were female (74.5%), while those with traumatic tears were more balanced (51.4% female). This is consistent with other reports that show a higher percentage of males with traumatic injuries^[37,38,40-42].

The average modified UCLA scale in this study was 33.7 in the non-traumatic group and 32.8 in the traumatic group. These results are similar to those found in the literature^[37,38,43]. As a score of 28-33 points is considered good, the non-traumatic group had a slightly higher score than the traumatic group. We expected to find better functional outcomes in patients with traumatic rotator cuff repairs, as the healing capacity of these patients is higher. These results therefore disproved our hypothesis.

Rotator cuff repairs lead to improved muscle strength and range of motion compared with preoperative measurements^[38,39,44,45]. This was one reason why we did not collect preoperative patient data. We observed that postoperative strength was reduced in the surgical shoulder compared with the unaffected side after a mean follow-up of 43 mo. Tear etiology did not impact strength recovery after rotator cuff repair compared with the uninjured limb.

Table 6 Affected *vs* unaffected shoulder strength

Strength	Affected side	Unaffected side
Mean	4.76	6.04
Median	5	6
Standard deviation	2.38	2.06
Coefficient of variation	50%	34%
Minimum	0	1
Maximum	11.5	12.5
Patients	86	86
Confidence interval	0.5	0.44
P-value	< 0.001	

Several factors influence the outcomes of rotator cuff repairs, including: Sex, duration of symptoms, and abduction and external rotation strength^[23,46]. However, in our study we could not identify any variable that was predictive of functional outcome.

In the patients in our study with traumatic rotator cuff repairs, it was likely that many already had tendon degeneration, characterized by reduced cellular activity, collagen disorganization, fibroblast apoptosis and decreased extracellular matrix synthesis^[29]. Chronic rotator cuff tears in older adults have a low healing potential and a high recurrence risk, even if treated surgically. This can be explained by degenerative changes in the tendon margin, even in cases with fatty infiltration below grade 2 on Goutallier scale. If these injuries had occurred in younger patients with acute and smaller injuries, the healing potential could be better because of low levels of apoptosis, fibrocartilaginous metaplasia and high rates of neoangiogenesis. The traumatic group could get better results in comparison with the non-traumatic group^[28].

Braune *et al*^[39] in 2003 compared range of motion and patient satisfaction after rotator cuff repairs after traumatic or non-traumatic tears. The traumatic group produced better postoperative results. However, in this study the average age was significantly lower in the traumatic group (mean 34.1 years) than in the non-traumatic (mean 54.1 years) group, as one of the inclusion criteria for the traumatic group was an age younger than 50 years.

The rotator cuff prevents degenerative processes, as it permits the formation of a closed joint space and participates in cartilage nutrition^[47]. A hypothesis as to why our findings were equivocal between traumatic and non-traumatic tears is that patients with traumatic tears may wait a relatively long period of time to seek medical aid. A diagnostic failure in primary medical care^[37] may also compromise treatment outcomes, as there may already be degenerative changes at the time of surgery. The late diagnosis of traumatic injuries can lead to surgical complications and poor results^[37,38,44]. Compared with early repairs (< 3 wk), traumatic rotator cuff tears have better functional results compared with delayed repairs (> 3 wk). Late treatment is associated with reduced tendon elasticity, increased repair tension, muscle atrophy and fatty degeneration. Increased repair

tension leads to a lower rate of healing and decreased viscoelastic properties. Further, injuries resulting from trauma are large or massive (> 2 tendons)^[37], which has a worse prognosis compared with minor injuries. Other authors^[37,45] found that the outcomes of early repairs are better than late repairs, although exact time cutoffs have not been defined.

In our study we obtained good results in both groups as rated by the modified UCLA scale. These findings support arthroscopic rotator cuff repairs of either traumatic or non-traumatic injuries. Limitations to our study include: A small sample ($n = 87$), our muscle strength measurement method, and the use of only one functional score.

The functional results of the arthroscopic rotator cuff repair of traumatic tears are equivocal to those measured after non-traumatic tears. Both groups display adequate overall results.

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COMMENTS

Background

Rotator cuff injuries are the leading cause of shoulder pain, and can cause functional limitation and decreased quality of life. The causes of rotator cuff tears are multifactorial. It is believed that degeneration is essential, and most tears are slow and progressive. In contrast, acute tears can occur after trauma. The aim of this study is to compare shoulder functional outcomes after arthroscopic rotator cuff repair of traumatic and non-traumatic tears.

Research frontiers

Surgical treatment of rotator cuff tears is currently widely performed, since the prevalence of this disease is up to 39% in the population, increasing with age. The research hotspot is to evaluate the functional outcomes after arthroscopic rotator cuff repair in patients with traumatic and non-traumatic injuries. This may help to understand the post-surgical function of these patients, and support clinical decision making.

Innovations and breakthroughs

Chronic rotator cuff tears in older adults have a low healing potential and a high recurrence risk, even if treated surgically. Because of the higher healing capacity of patients with traumatic rotator cuff repairs, it was expected that this group of patients would have better functional outcomes. In previous data, traumatic tears had better postoperative results (range of motion and patient satisfaction) than non-traumatic tears, but the average age was significantly lower in the traumatic group than in the non-traumatic group, as one of the inclusion criteria for the traumatic group was an age younger than 50 years. In this study, the average age of the traumatic group was similar to the non-traumatic group, and the functional outcomes were similar in both groups. In this study, there was a higher percentage of males with traumatic injuries in comparison with non-traumatic injuries, and a good result in modified University of California, Los Angeles (UCLA) scale evaluation in both groups. These results are similar to those found in the literature.

Applications

The functional results of the arthroscopic rotator cuff repair are similar in traumatic and non-traumatic tears, with adequate overall results in both groups. These findings support arthroscopic rotator cuff repairs of either traumatic or non-traumatic injuries.

Terminology

The rotator cuff is a group of four tendons (subscapularis, supraspinatus, infraspinatus and teres minor) that cover the humeral head and plays an important role in the strength, mobility and stability of the shoulder by fixing the humeral head to the glenoid. The treatment for rotator cuff tears should be clinical or surgical. When surgical treatment is indicated, rotator cuff repairs can be performed through either arthroscopic or open approaches. Arthroscopic surgery is performed through micro incisions and preserves the deltoid muscle insertion.

Peer-review

The primary outcome was modified UCLA score validated for the Portuguese language, which takes into account pain, function, range of motion, strength and patient satisfaction.

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Ipsilateral femur and tibia fractures in pediatric patients: A systematic review

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Abstract

AIM

To better understand how pediatric floating knee injuries are managed after the wide spread use of new orthopaedic technology.

METHODS

We searched EMBASE, COCHRANE and MEDLINE computerized literature databases from the earliest date available in the databases to February 2017 using the following search term including variants and pleural counterparts: Pediatric floating knee. All studies were thoroughly reviewed by multiple authors. Reference lists from all articles were scrutinized to identify any additional studies of interest. A final database of individual patients was assembled from the literature. Univariate and multivariate statistical tests were applied to the assembled database to assess differences in outcomes.

RESULTS

The English language literature contains series with a total of 97 pediatric patients who sustained floating knee injuries. Patients averaged 9.3 years of age and were mostly male (73). Approximately 25% of the fractures were open injuries, more tibia (27) than femur (10). Over 75% of the fractures of both the tibia and the femur involved the diaphysis. More than half (52) of the patients were treated non-operatively for both fractures. As a sequela of the injury 32 (33%) patients were left with a limb length discrepancy, 24 (25%) patients had lengthening of the injured limb at follow up, while 8 (8%) had shortening of the affected limb. Infection developed in 9 patients and 3 had premature physal closure. Younger patients were more likely to be treated non-operatively ($P < 0.001$) and patients treated with operative intervention had statistically significant shorter hospital length of stays ($P = 0.001$).

CONCLUSION

Given the predominance of non-operative management

in published studies, the available literature is not clinically relevant since the popularization of internal fixation for pediatric long-bone fractures

Key words: Pediatrics; Femur; Tibia; Fracture; Floating knee

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Core tip: Advances in orthopaedic technology and implants have dramatically changed the management of femur and tibia fractures in children, when treated in isolation. No current day study, however, has examined the effects of this advancement on the higher energy pediatric floating knee injury. This systematic review indicates a gap in the literature and the need for further investigation.

Anari JB, Neuwirth AL, Horn BD, Baldwin KD. Ipsilateral femur and tibia fractures in pediatric patients: A systematic review. *World J Orthop* 2017; 8(8): 638-643 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v8/i8/638.htm> DOI: <http://dx.doi.org/10.5312/wjo.v8.i8.638>

INTRODUCTION

Isolated femur and tibia fractures are a frequent occurrence in the pediatric age group; these two diagnoses account for 2 of the 4 most frequent pediatric orthopaedic injuries requiring hospitalization^[1]. In 1997 pediatric orthopaedic trauma accounted for 84000 in-patient hospital admissions, 43.2% of which was accounted for by tibia (21.5%) and femur (21.7%) fractures^[2]. Although these two fractures occur often in the pediatric population their prevalence in the ipsilateral limb, resulting in a floating knee, is a rare event, generally resulting from a high energy mechanism^[3]. Literature on ipsilateral tibia and femur fractures (floating knee) has primarily focused on the adult patient population leaving the optimal treatment of pediatric patients undefined.

Two unique classifications systems exist to describe these fracture patterns. Letts *et al*^[3] in 1986 first grouped these fractures by region of fracture in the bone as well as whether the fracture was open or closed. The Letts-Vincent pediatric floating knee classification system is as follows: Type A-both fractures diaphyseal and closed; type B-both fractures closed with one diaphyseal and one metaphyseal fracture; type C-both fractures closed with one diaphyseal and epiphyseal fracture; type D-one fracture is open; and type E-both fractures are open^[3]. The Bohn-Durbin classification system, published in 1991, is the other classification system for pediatric floating knee injuries. It has 3 types: Type 1-double shaft pattern; type 2-juxta-articular pattern; and type 3-epiphyseal component^[4]. Neither classification system however

provides therapeutic guidance or offers prognostic value.

Given the rare nature of the injury pattern, limited data exist in the literature. No published series includes more than 30 patients and no manuscript on pediatric floating knee injuries (excluding case reports) has been published in the English language literature in over a decade. Neither large prospective studies nor aggregate data reviews have been performed to further elucidate the best classification system or treatment algorithm for pediatric floating knee injuries. The objective of this study is to synthesize the literature and to identify factors associated with both good and poor outcomes of these complex pediatric injuries in order improve care of this high energy fracture pattern.

MATERIALS AND METHODS

We searched EMBASE, COCHRANE and MEDLINE computerized literature databases from the earliest possible date to February 2017 using the search term "pediatric floating knee". Reference lists from all articles were scrutinized to identify any additional studies of interest. All studies were thoroughly reviewed and included in the study if they met the following criteria: (1) written in English language; (2) had a level I, II, III, IV, or V study design classified by "Journal of Bone and Joint Surgery" criteria; (3) articles had patient information listed within article; and (4) patient age under 18 years old. Two authors performed the initial search (Jason B Anari, Alexander L Neuwirth) and three authors (Jason B Anari, Alexander L Neuwirth, Keith D Baldwin) independently reviewed the references of the qualifying papers and selected those studies that fit based on the aforementioned criteria. In the final phase of review, full text review, no disagreement occurred regarding which studies would be included. Univariate and multivariate statistical tests were applied to the assembled database to assess differences in outcomes.

When assessing for nonunion and malunion we applied the criteria previously described by Bohn and Durbin^[4]. Malunion of the femur required the following criteria: 30° anterior, 15° valgus, 5° posterior or varus, or more than 2 cm of shortening. Malunion of the tibia is defined by angulation greater than 5° in any plane or more than 1 cm of shortening. Rotational nonunions were defined as more than 20° of external rotation or any internal rotation compared to the contralateral side. Nonunion was defined as the absence of bridging callus and persistent fracture lines beyond 4 mo.

Classification of the open fractures was based on the classification published by Gustilo *et al*^[5] in 1984. Limb length discrepancies were diagnosed by clinical exam and measured on scanograms. Length of stay was determined by the number of days following admission until discharge to home, rehab, or another non-hospital facility. Infections included any fracture or wound requiring irrigation and debridement or treatment with antibiotics. Any additional operations performed on the

Table 1 Patient demographics and characteristics

Characteristics	n (%)
No. of patients	97
Age (yr)	9.3
Follow up (mo)	39.99
Open fracture	48
Tibia	27
Gustillo Anderson 1	5 (18.52)
Gustillo Anderson 2	11 (40.74)
Gustillo Anderson 3a	7 (25.92)
Gustillo Anderson 3b	2 (7.41)
Gustillo Anderson 3c	2 (7.41)
Femur	10
Gustillo Anderson 1	4 (40.00)
Gustillo Anderson 2	2 (20.00)
Gustillo Anderson 3a	2 (20.00)
Gustillo Anderson 3b	1 (10.00)
Gustillo Anderson 3c	1 (10.00)
Not specified	11
Fracture pattern	
Tibia	97
Diaphysis	75 (77.32)
Metaphysis	9 (9.28)
Epiphysis	13 (13.40)
Femur	97
Diaphysis	73 (75.26)
Metaphysis	15 (15.46)
Epiphysis	9 (9.28)
Management	
ORIF femur and non-operative tibia	14
ORIF tibia and non-operative femur	12
ORIF tibia and femur	19
Non-operative tibia and femur	52

ORIF: Open reduction internal fixation.

floating extremity were included under 2nd procedures.

We identified 5 articles from MEDLINE, 4 articles from EMBASE, all of which were duplicates, and zero articles from COCHRANE. Initially, articles were eliminated based on title relevance. Articles were then eliminated by abstract for failing to meet inclusion criteria. We finally reviewed the full text of the remaining 6 papers and 1 was eliminated for meeting exclusion criteria. References from the remaining 5 papers were evaluated and 1 additional study was identified that met inclusion criteria leaving us with 6 articles for the systematic review: Four case series and 2 case reports.

Data on 97 patients were then collected from the 6 articles that met inclusion criteria (Table 1). The average age of patients presenting with a floating knee injury was 9.3 years old. The male to female ratio was approximately 3:1. The majority of open fractures occurred in the tibia (27/48), with most injuries being Gustilo-Anderson grade 2. Seventy-five percent of the fractures for both the tibia (75/97) and the femur (73/97) occurred in the diaphysis. Over half (52/97) of the patients with floating knee injuries had both fractures definitively treated non-operatively with casting and/or traction. Average follow-up was 39.99 mo.

Table 2 Complications

Characteristics	n (%)
Limb length discrepancy	32
Overgrowth	24 (75.00)
Undergrowth	8 (25.00)
Non-union	7
Femur	3 (42.86)
Tibia	4 (57.14)
Mal-union	20
Femur	11 (55.00)
Tibia	9 (45.00)
Infection	9
2 nd surgery	13
Premature physeal closure	3

Univariate *P* values were calculated on the basis of independent sample *t*-tests in cases of continuous variables, and Pearsons χ^2 and Fisher's exact tests were used to calculate differences in dichotomous or categorical outcomes. All statistics were calculated using SPSS version 20.0 (SPSS Inc, Chicago, IL).

RESULTS

In the assembled literature, 32 patients (33%) had limb length discrepancies at their final post-operative visit (Table 2). The majority of these were lengthening of the injured limb, presumably from overgrowth (24/32). Eight patients had shortening of the injured limb, most likely from healing in a shortened position, since only 3 patients with a floating knee experience premature physeal closure. Infection occurred in 9/97 patients. Thirteen patients required additional surgery after initial treatment of the floating knee injury. The two most prevalent additional procedures were osteotomy (4) for angulation or limb length discrepancy and revision fixation (4). Infections, which were mostly superficial pin track infections, also included deep space infections (more commonly involving the tibia than the femur). Femoral nonunion and malunion occurred in 3 and 11 patients, respectively. Tibial nonunion occurred in 4 patients, while malunion was present in 9.

Univariate analysis in Table 3 shows that younger children were more likely to be treated non-operatively than their adolescent counterparts (*P* < 0.001). Patients who were treated operatively for either their femur fracture, tibia fracture, or both had statistically significant shorter length of stays (*P* = 0.001). When evaluating length of stay in patients older or younger 10 years of age, this trend is accentuated. No association was noted between management of injury and resultant limb length discrepancy for either undergrowth or overgrowth.

DISCUSSION

Ipsilateral fractures of the tibia and femur in the pediatric patient are rare injuries. There is not a consensus

Table 3 Univariate analysis

Characteristics	mean	P
Age (yr)		< 0.001
ORIF femur and non-operative tibia	11.47	
ORIF tibia and non-operative femur	10.07	
ORIF tibia and femur	11.45	
Non-operative tibia and femur	7.7	
Length of stay (d)		0.001
ORIF femur and non-operative tibia	27.26	
ORIF tibia and non-operative femur	100.86	
ORIF tibia and femur	18	
Non-operative tibia and femur	37.35	
Limb length discrepancy overgrowth (mm)		0.372
ORIF femur and non-operative tibia	1.37	
ORIF tibia and non-operative femur	1.9	
ORIF tibia and femur	2.27	
Non-operative tibia and femur	2.81	
Limb length discrepancy undergrowth (mm)		0.514
ORIF femur and non-operative tibia	1.2	
ORIF tibia and non-operative femur	6	
ORIF tibia and femur	2.7	
Non-operative tibia and femur	2.75	

ORIF: Open reduction internal fixation.

regarding treatment of this fracture pattern in children and adolescents, and optimal treatment remains controversial. Historically, however, pediatric floating knee injuries have been treated non-operatively with traction and casting.

In 1975, Blake *et al*^[6] reported one of the first case series on adult and pediatric patients with ipsilateral tibia and femur fractures. They noted the floating knee injury pattern to be associated with high-energy mechanisms of injury as well as to have a high rate of nonunion and malunion. Blake *et al*^[6] treated most of the floating knee injuries with skeletal traction and casting, however they concluded that emerging techniques of osteosynthesis would alter the treatment options.

In 1986, Letts *et al*^[3] reported on floating knee injuries in children. Over an 11-year period they treated 15 patients with ipsilateral tibia and femur fractures. Letts acknowledged the difficulty in treating this fracture pattern and recognized the complications associated with non-operative modalities such as casting and traction alone. Ultimately, Letts *et al*^[3] concluded that at least one of the two fractures should be rigidly fixed when treating pediatric patients with floating knee injuries.

The largest collection of pediatric patients with ipsilateral tibia and femur fractures is Bohn *et al*^[4]'s published case series from 1991. These authors were the first to suggest a treatment algorithm based on patient age, and they created their own classification system in an attempt to guide treatment by fracture type. For patients under 10 years of age they suggested a short leg cast for the tibia fracture and 90°-90° femoral-pin traction (with subsequent conversion to a hip spica cast at 4 wk) for the femur. In adolescent patients they recommended operative treatment of

the femur fracture and non-operative treatment of the tibia fracture. The authors additionally identified general indications for operative treatment for each fracture. Severe head trauma, adolescent patient, severe soft tissue injury and inability to maintain reduction were indications for surgical treatment of the femur while severe soft tissue injury and inability to maintain reduction were indications for the tibia^[4]. Importantly, given the risk of limb length discrepancy and deformity, the concept of longitudinal follow up until skeletal maturity was raised by Bohn and Durbin in their article.

In 2000, Yue *et al*^[7] reported another large case series of pediatric patients with floating knee injuries. The authors claimed that the rate of limb deformity and limb length discrepancy were decreased when fracture patterns were treated with operative intervention^[7]. They recommended that all patients with floating knee injuries, regardless of age, be treated with operative fixation of the femoral fracture. The most recently published case series from Arslan *et al*^[8] in 2003 reiterates the importance of operative fixation for patients with floating knee injuries independent of age. The authors additionally comment on the inadequacy of the Bohn and Durbin as well as the Letts classification systems in directing treatment plans for patients with floating knee injuries.

Ipsilateral fractures of the tibia and femur are rare but severe injuries in children and adolescents. They often result from a high-energy mechanism of injury. The literature currently available to the practicing orthopaedic surgeon is of limited value given the historic nature of the studies and available treatment strategies at the time of investigation. The articles reviewed, however, do demonstrate a high complication rate in the treatment of these injuries. The advent of newer techniques for treating long bone fractures in children and adolescents (such as flexible elastic nailing and submuscular plating) allow for surgeons to achieve relative stability in diaphyseal long bone fractures through minimally invasive approaches. In addition there are multiple techniques now available for reduction and stabilization of pediatric physeal and juxta-articular fractures. Long bone injuries in children and adolescents are now less frequently treated with traction and casting in the United States. Surgical fixation of isolated length-stable pediatric tibia and femur fractures allows for quicker mobilization, discharge from in-patient care, and return to school as well as activities of daily living (Figure 1)^[9].

This study has limitations, which were largely due to the weakness of member studies. The studies were all uncontrolled, and many were small heterogeneous case series. This type of literature severely limits the conclusions one can draw. Many modern techniques, which are available today, were not evaluated in many of the member studies. However, our study has value in that it identifies the gap in the literature, and synthesizes the available outcomes so that the pediatric



Figure 1 A floating knee injury in a pediatric patient. A: AP of the right proximal femur showing an oblique diaphyseal fracture with a butterfly fragment; B: AP of the midshaft right femur confirming the oblique diaphyseal fracture; C: AP of the right tibia showing an oblique diaphyseal fracture; D: Lateral of the right tibia confirming the oblique diaphyseal fracture (E) AP and (F) lateral of the right femur and (G) AP and (H) lateral of the right tibia at 12 wk with osseous union of both diaphyseal fractures.

orthopedic surgeon can counsel the patient with this rare injury.

The available literature on this uncommon injury is sorely lacking. The series available for review are comprised of heterogeneous treatments, which are largely non-operative. Many school-age children with long bone fractures are now treated with internal fixation that provides relative or absolute stability of these fractures. New studies are needed to see if this approach is beneficial for pediatric floating knee injuries. A study evaluating current technology with consistent use of a single classification system that helps direct treatment will better elucidate how Pediatric Orthopaedic surgeons should manage this highly complex and often severe pediatric injury.

COMMENTS

Background

Historically pediatric patients who had injuries of both the femur and tibia were treated in traction and casting for weeks in the hospital.

Research frontiers

Open reduction and internal fixation has become more commonplace for pediatric long-bone fracture management given the advancement in orthopaedic technology.

Innovations and breakthroughs

Flexible nails for the femur and the tibia as well as adolescent intramedullary rods have changed the management of pediatric long bone fractures in isolation. No one is yet to comment on this technology in the setting of the more severe floating knee injury in pediatric patients.

Application

Mobilizing patients soon leads to improved patient satisfaction, shorter hospital

stays, less costly time away from work, and overall better outcomes. Using this technology to get children back home and to school sooner and parents to work is beneficial to the hospital, the healthcare system, the patient, and the parents.

Terminology

Floating knee-injuries to both the femur and tibia resulting in the knee joint not being connected to either long bone.

Peer-review

Well-organized paper.

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Femoral positioning influences ipsi-and contralateral anterior cruciate ligament rupture following its reconstruction: Systematic review and meta-analysis

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Abstract

AIM

To systematically review the incidence of ipsilateral graft re-rupture and contralateral anterior cruciate ligament (ACL) rupture following its reconstruction, with special attention to the femoral drilling technique.

METHODS

Systematic review and meta-analysis of high-level prospective studies searched in MEDLINE database following PRISMA statement. The rate of ipsilateral graft re-rupture and contralateral rupture in patients submitted to either transtibial (TT) technique (isometric) or anteromedial (AM) technique (anatomic) was compared.

RESULTS

Eleven studies met the criteria and were included in final analysis. Reconstructions using the AM technique had a similar chance of contralateral ACL rupture when compared to the chance of ipsilateral graft failure (OR = 1.08, $P = 0.746$). In reconstructions using TT technique, the chance of contralateral ACL rupture was approximately 1.5 times higher than ipsilateral graft failure (OR = 1.49, $P = 0.048$). Incidence of contralateral lesions were similar among the techniques TT (7.4%) and AM (7.0%) ($P = 0.963$), but a trend could be noticed with a lower incidence of lesion in the ipsilateral limb when using the TT technique (4.9%) compared to the AM technique (6.5%) ($P = 0.081$).

CONCLUSION

ACL reconstruction by TT technique leads to lower incidence of graft re-injury than contralateral ACL lesion. There is no difference between the chance of re-injury after AM technique and the chance of contralateral ACL lesion (native ligament) with either technique.

Key words: Anterior cruciate ligament; Anterior cruciate ligament reconstruction; Arthroscopy; Graft survival

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Core tip: There is no convincing evidence that anatomic reconstruction leads to better clinical outcomes than transtibial (TT) reconstruction. Moreover, data suggests that it could lead to an increased risk of graft re-rupture. We found that anterior cruciate ligament (ACL) reconstruction by TT technique led to lower incidence of graft re-rupture than contralateral ACL lesion. The chance of graft re-rupture after anteromedial (AM) technique was the same of contralateral ACL lesion. There was no difference between contralateral lesion after both techniques and re-rupture after AM technique, what could mean that re-rupture chance after AM technique is indeed closer to normal knee, and, in fact, it is the TT technique's re-tear incidence that is lower than it should be.

de Campos GC, Teixeira PEP, Castro A, Alves Junior WM. Femoral positioning influences ipsi-and contralateral anterior cruciate ligament rupture following its reconstruction: Systematic review and meta-analysis. *World J Orthop* 2017; 8(8): 644-650 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v8/i8/644.htm> DOI: <http://dx.doi.org/10.5312/wjo.v8.i8.644>

INTRODUCTION

Optimal reconstruction technique for an anterior cruciate ligament (ACL) tear still on debate. In the last fifteen years literature has shown a significant shift in trends regarding graft positioning^[1]. The "isometric" femoral graft positioning, made through the tibial tunnel (transtibial technique) and very popular during the last two decades of the twentieth century, is gradually being loathed^[2]. Since the introduction of the anterior cruciate anatomic reconstruction concept^[3], the pursuit of the ideal graft positioning has led to the so-called "anatomic" single-bundle reconstruction techniques, which can be accomplished by either by an anteromedial approach^[4,5] as well as an outside-in femoral drilling^[6].

Despite the plethora of anatomical and biomechanical studies suggesting incorrect graft positioning and inadequate knee rotational stability with transtibial (TT) femoral drilling technique, there is no convincing evidence that anatomic reconstruction leads to better clinical outcomes^[7]. Moreover, recent data suggests that the anteromedial (AM) technique for femoral drilling

could lead to an increased risk of graft re-rupture^[8].

We hypothesized that the increased risk of graft re-rupture observed in anatomical reconstructions could in fact represent an approximation to the "normal knee" ACL rupture risk, that could be represented by the risk of contralateral knee lesion. This also would explain the odd finding that there is a higher incidence of contralateral knee ACL lesion when compared to graft re-lesion following ACL reconstruction by isometric technique^[9].

Therefore, the aim of this study is to systematically review the incidence of ipsilateral graft re-rupture and contralateral ACL rupture following ACL reconstruction, with special attention to the femoral drilling technique.

MATERIALS AND METHODS

Systematic review and meta-analysis of studies including patients submitted to ACL reconstruction, registered at PROSPERO under the number CRD 42015019336. PRISMA statement guidelines were followed for conducting and reporting meta-analysis data.

Literature review

On September 13, 2015, a systematic literature search of the MEDLINE database was performed independently by two of the authors (Gustavo Constantino de Campos and Paulo Eduardo Portes Teixeira) using the following terms: "Anterior cruciate ligament" AND "contralateral" AND "reconstruction" AND "follow-up". The initial search yielded 189 results. Eligibility criteria were original studies that included adult patients submitted to ACL reconstruction, in English language. Title and abstract evaluation suggested 156 articles for full text revision. Studies were excluded if did not specifically described drilling technique for ACL femoral tunnel confection, did not report the incidence of ipsilateral graft failure and incidence of contralateral ACL lesion during follow-up, if they were experimental studies (biomechanics or animal), if patients were submitted to revision surgery, double bundle or multiple ligaments reconstruction, or graft selection comprising allograft, artificial devices or harvested from contralateral knee. Risk of bias was minimized including only grade I to III prospective studies with a minimum of 75% of patients at final follow-up.

From the 156 articles reviewed, 145 articles were excluded, resulting in 11 articles for final analysis^[10-20]. The references of the remaining eleven articles were reviewed with no additional studies for inclusion identified. These 11 studies provided the data for the present analysis. Literature review is summarized in Figure 1.

Data extraction

Extracted data included type of study, evidence level, patient demographics, follow-up duration, loss of follow-up, surgical technique, graft choice, ACL graft re-lesion

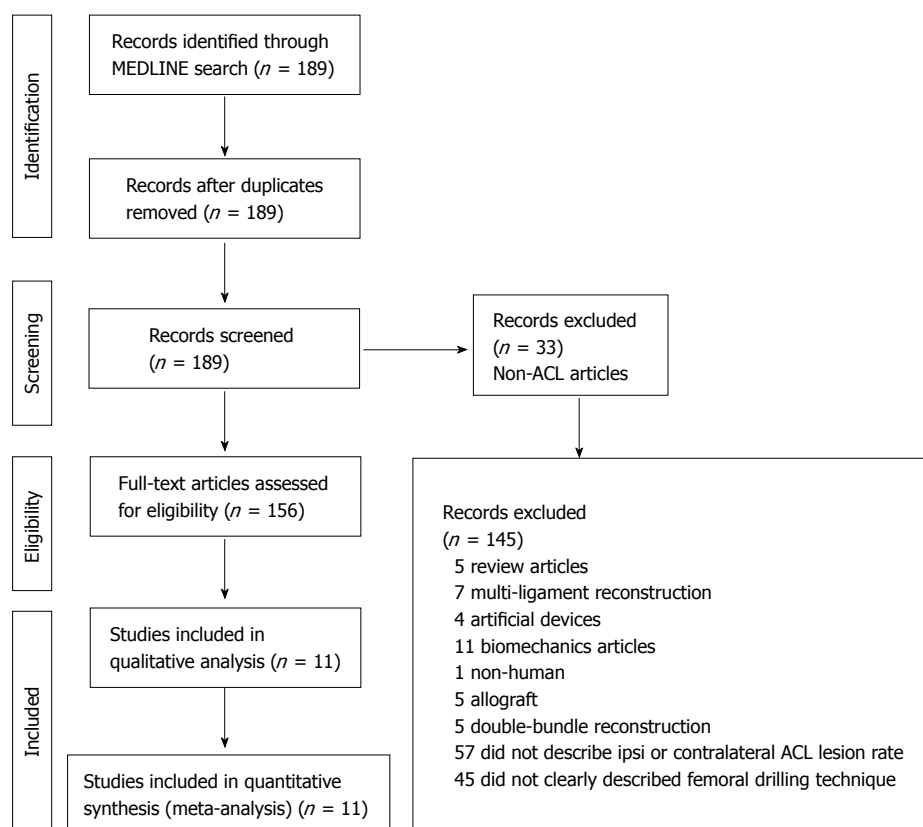


Figure 1 Prisma flow diagram. ACL: Anterior cruciate ligament.

incidence and contralateral ACL rupture incidence. Data were extracted by two authors independently (GCC and PEPT). Discrepancies were resolved by consensus.

Statistical analysis

A meta-analysis of the incidence of contralateral vs ipsilateral lesions to each of surgical techniques (AM and TT) was performed by "Comprehensive Meta-Analysis software version 3.3.070". The heterogeneity of variances between studies was examined by χ^2 test for heterogeneity and I^2 statistics (proportion of the total variance due to heterogeneity) and χ^2 (effect size variance between studies)^[21,22]. When a significant heterogeneity was observed between studies, the combined effects across studies were analyzed by random effects model. When there was no significant heterogeneity between studies, these effects were analyzed using fixed effects model^[22].

The estimate of the pooled effect (pooled odds ratio) between studies was calculated using the Mantel-Haenszel method (MH OR). Publication biases were analyzed by the asymmetry in the Begg and Mazumdar's funnel plot^[23]. Additionally, an association analysis between the surgical technique used (AM or TT) and the incidence of total ipsilateral and contralateral lesions of all publications was performed using χ^2 2 × 2 test statistic in SPSS 18.0 software (SPSS Inc., Chicago, United States).

The chance of injury occurrence was calculated by OR

using simple logistic regression in which was considered the sum of the number of events (contralateral or ipsilateral lesions) and the sum of the number of cases of all publications that have used the technique AM or TT separately. The significance level (α) used for all analyzes was 5% ($P < 0.05$).

RESULTS

Follow-up

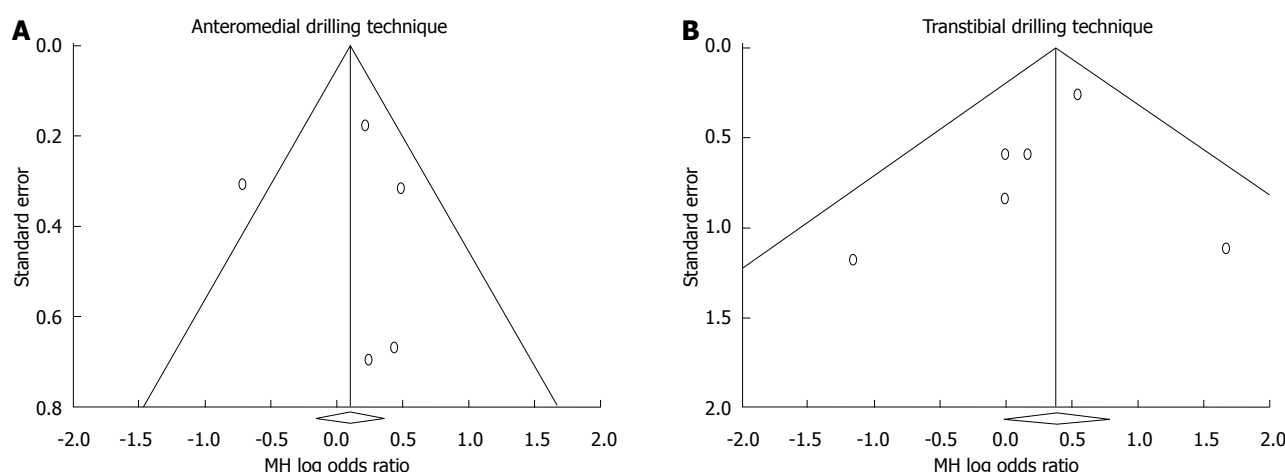
All studies had a minimum of 2 years of follow-up after ACL reconstruction. The duration of follow-up's ranged from 2 to 15 years. Data concerning the incidence of lesions were based on the total amount of individuals who have completed 100% of follow-up for each study. The percentage of individuals who completed the follow-up in each study ranged from 75% to 98% (Table 1).

Quality evaluation and potential biases

Study quality was assessed as recommended by previous studies^[23,24]. Of the eleven studies included in this meta-analysis, 6 (55%) were classified as level of evidence 1, 3 (27%) with level of evidence 2 and 2 (18%) with evidence of Level 3 (Table 1). The potential bias across studies were evaluated by Begg and Mazumdar's funnel plot for the incidence of contralateral and ipsilateral lesions in each of the AM and TT techniques, which were predominantly symmetrical, suggesting lack of significant biases in the publications

Table 1 Data of the studies *n* (%)

Author	Year	Evidence level	No. of initial patients	No. of patients included in follow-up	Follow-up (yr)	No. of contralateral injuries	No. of Ipsilateral injuries
Anteromedial drilling technique							
Webb	2013	3	200	181 (91)	15	19 (10.5)	35 (19.3)
Shelbourne	2009	2	1820	1415 (78)	14	75 (5.3)	61 (4.3)
Pinczewsky	2007	2	180	178 (99)	10	29 (16.3)	19 (10.7)
Sajovic	2006	1	64	61 (95)	5	5 (8.2)	4 (6.6)
Shaieb	2002	1	82	70 (85)	2	6 (8.6)	4 (5.7)
Total	-	-	2346	1905 (81)	-	134 (7.0)	123 (6.5)
Transtibial drilling technique							
Barenius	2014	1	164	134 (82)	14.1	6 (4.5)	6 (4.5)
Webster	2014	3	750	561 (75)	4.8	42 (7.5)	25 (4.5)
Holm	2010	1	72	57 (79)	10	7 (12.3)	6 (10.5)
Keays	2007	2	62	62 (100)	6	5 (8.1)	1 (1.6)
Drogset	2005	1	41	38 (93)	2	1 (2.6)	3 (7.9)
Aune	2001	1	72	64 (89)	2	3 (4.7)	3 (4.7)
Total	-	-	1161	916 (79)	-	64 (7.4)	44 (4.9)

**Figure 2** Funnel plot for the incidence of contralateral and ipsilateral lesions in each of the anteromedial (A) and transtibial (B) techniques included in the meta-analysis. MH: Mantel-Haenszel.

included in the meta-analysis (Figure 2).

Incidence of ipsilateral vs contralateral rupture

After the meta-analysis and combining the data, it was observed that ACL reconstructions using the AM technique had a similar chance of contralateral ACL rupture when compared to the chance of ipsilateral graft failure (MH OR = 1.08, 95%CI: 0.67 to 1.75, $P = 0.746$; Figure 3). However, after reconstructions using the TT technique, the chance of contralateral ACL rupture was approximately 1.5 times higher than the chance of ipsilateral graft failure (MH OR = 1.49, 95%CI: 1.00 to 2.21, $P = 0.048$, Figure 3). There was no heterogeneity of variances between studies using the TT technique ($I^2 = 0.0\%$, $\chi^2 = 0.0$, $P = 0.517$, Figure 3).

Nevertheless, those who used AM technique showed significant heterogeneity of variances ($I^2 = 56.9\%$, $\chi^2 = 0.151$, $P = 0.054$, Figure 3). Finally, from the publications included in the present meta-analysis (Table 1), no differences in the incidence of contralateral lesions were identified among the techniques TT (7.4%)

and AM (7.0%) (OR = 0.99, 95%CI: 0.73 to 1.35, $P = 0.963$). But a trend could be noticed with a lower incidence of lesion in the ipsilateral limb when using the TT technique (4.9%) compared to the AM technique (6.5%) (OR = 0.73, 95%CI: 0.51 to 1.04, $P = 0.081$).

DISCUSSION

The present study found no difference between the risk of an ipsilateral graft re-rupture and a contralateral ACL rupture in individuals operated with the AM technique. There was also no difference in the risk of a contralateral ACL rupture when comparing both techniques (7%). However, the present analysis found a lower rate of ipsilateral graft re-rupture in patients operated with TT technique (4.9%; $P = 0.048$). This is the first analysis focusing the influence of femoral drilling technique over the graft failure and contralateral ACL lesion after ACL reconstruction.

Ipsilateral graft re-lesion is, for obvious reasons, an undesirable event, occurring in 1.8%^[14] to 10.4%^[25]

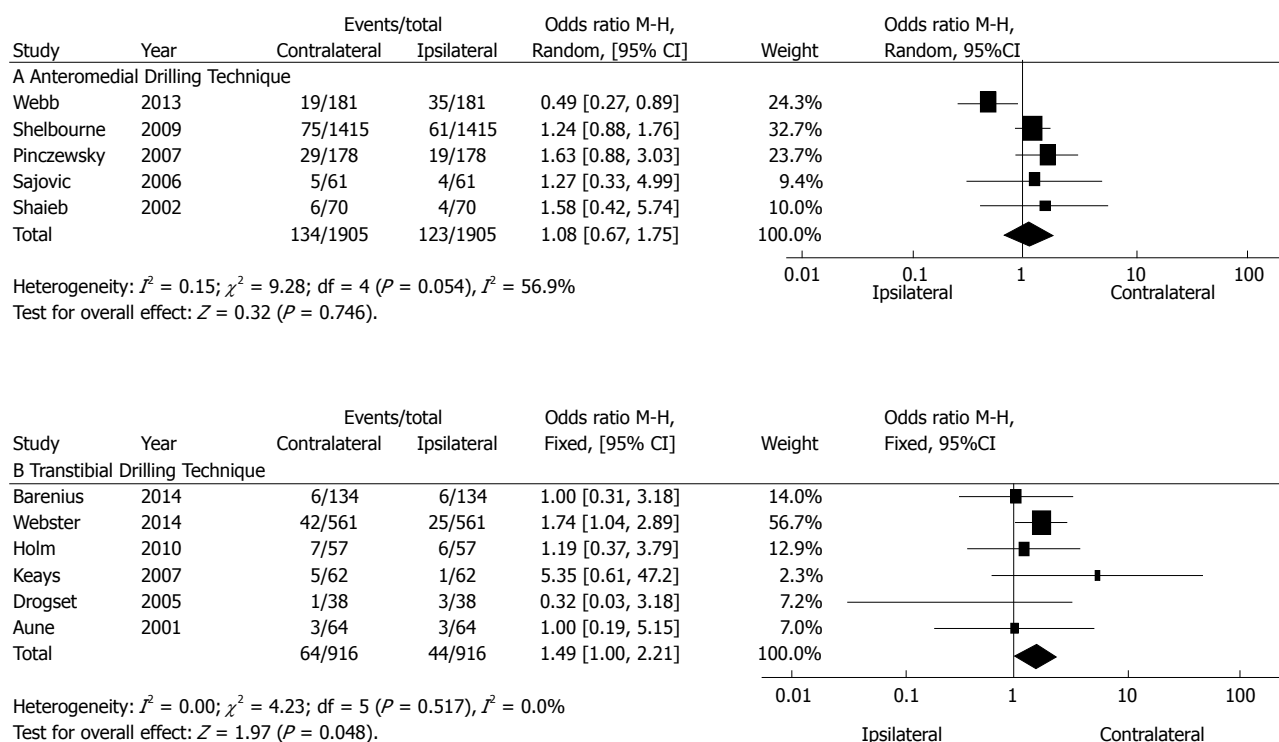


Figure 3 Results of individual studies along with a Forest plot that graphically displays the point estimates on a common scale surrounded by the 95%CI (indicated by the horizontal lines). The diamond represents the pooled effect between studies. M-H: Mantel-Haenszel; df: Degrees of freedom.

of ACL reconstructed patients during the follow-up. Literature shows higher rates of contralateral ACL lesions than ipsilateral graft failure after ACL reconstruction^[9]. An explanation to this finding could be inadequate rehabilitation^[16] or even the assumption that the neoligament would be stronger than the original ACL^[16]. Some authors attribute such finding to the protective role of the uninjured limb that renders it more suitable to lesion^[26].

However, recent studies found a decrease in graft in situ forces when positioned in more vertical locations (isometric position), indicating that the femoral tunnel drilled through transtibial approach will result in a more vertical graft with in situ force lower than the in situ force found in the native ACL^[27-29]. Therefore, the lower graft failure rates found in TT reconstruction could be because the neoligament simply is not submitted to the physiological forces that occur in the "normal" knee. With that in mind, one could speculate that it is not the AM technique that presents a higher failure rate, but the TT graft failure rate that is lower than it should be.

Anatomic ACL reconstruction results in graft inclination angle closer to the native ACL inclination angle and graft force and knee anterior laxity closer to those of the native knee^[29]. It is our understanding that this could be the explanation to the findings of the present analysis, since we found same risk of contralateral ACL rupture ("normal" knee) for both techniques, with no difference for graft failure in the AM group (7%), and lower incidence of ipsilateral graft failure in TT group (4.9%, $P = 0.048$).

It is fundamental, thus, to provide information regarding femoral drilling technique when discussing ipsi or contralateral lesions rates during follow-up. Most of studies just focus on the graft choice and patient demographics. The vast majority of studies initially included in our analysis did not adequately describe the ACL reconstruction technique used. This is in accordance to van Eck *et al.*^[30], who examined 74 studies that claimed to use "anatomic technique" for ACL reconstruction and found a gross under-reporting of specific operative technique data.

Rahr-Wagner *et al.*^[8] found increased risk of revision in patients undergone to ACL reconstruction with femoral drilling through AM portal when compared to TT technique in the Danish Knee Ligament Reconstruction Register. They explained this finding as a result of a learning curve due to the introduction of a new and more complex technique. The higher force over the more anatomically placed grafts could be a more accurate explanation.

Our results indicate that the increased risk is in fact an approximation to the expected failure rate of the normal knee, that could be represented by the rate of contralateral ACL lesion. van Eck *et al.*^[31] found that the majority of graft failures following anatomic ACL reconstruction occurred between six and nine months postoperatively, precisely the commonly recommended period for return to sports. Although there has been a transition toward the "anatomic" reconstruction over the last decades, rehabilitation protocols still the same. Maybe the higher forces over the graft could alter the

time frame for complete graft healing and maturation. More studies are needed on that matter.

In another point of view, one can argue that, since there is no convincing data on the superiority of anatomic technique regarding clinical outcomes, it would be better to choose a technique with a lower rate of graft failure (TT technique). This question will only be answered as longer follow-up of anatomic reconstruction series successfully demonstrates better clinical outcomes and lower evolution to osteoarthritis.

We acknowledge that this meta-analysis has strengths and limitations. One limitation is the lack of demographic data, such as age, gender, body mass index and level of activity. Post-operative rehabilitation protocols were not analyzed or even considered. We acknowledge the importance of rehabilitation data. However, meta-analysis was performed comparing two groups operated by the same authors, therefore subjected to same rehabilitation protocols. Also, we did not include anatomic reconstruction by out-in femoral drilling technique. We chose to use only AM technique to standardize our analysis.

In addition, we were not able to show the data on direct comparison between AM and TT techniques on graft failure and contralateral ACL rupture. To perform this comparison and present it in a meta-analysis format, the comparison effect between techniques would have to be presented individually in each study selected for this meta-analysis. All selected studies for this review were independent and presented only intra-technical comparisons. Although we performed an exploratory analysis to test the differences between the incidences of graft failure and contralateral ACL rupture among AM and TT techniques, it could be biased. This issue is still a gap in the literature and more clinical studies are needed to conduct future meta-analyses to clarify the subject. The major strength is the rigorous criteria used. We only included studies that reported both ipsi- and contralateral failure information, thus ensuring proper comparison when performing the meta-analysis. Moreover, we only included high quality prospective studies with high level of evidence and loss of follow-up lower than 25%.

The ACL reconstruction by transtibial technique leads to lower incidence of graft re-injury than contralateral ACL lesion. There is no difference between the chance of re-injury after anteromedial technique and the chance of contralateral ACL lesion (native ligament).

COMMENTS

Background

Optimal reconstruction technique for an anterior cruciate ligament (ACL) tear still on debate. Evidence regarding the influence of graft femoral positioning over ipsilateral graft re-lesion and contralateral rupture following ACL reconstruction is conflicting.

Research frontiers

Since the introduction of the anterior cruciate anatomic reconstruction concept, the pursuit of the ideal graft positioning has led to the so-called "anatomic"

single-bundle reconstruction techniques. However, despite the plethora of anatomical and biomechanical studies suggesting incorrect graft positioning and inadequate knee rotational stability with transtibial (TT) femoral drilling technique, there is no convincing evidence that anatomic reconstruction leads to better clinical outcomes. Moreover, recent data suggests that the anteromedial (AM) technique for femoral drilling could lead to an increased risk of graft re-rupture.

Innovations and breakthroughs

This is the first analysis focusing the influence of femoral drilling technique over the graft failure and contralateral ACL lesion after ACL reconstruction. The authors found that ACL reconstruction by TT technique led to lower incidence of graft re-injury than contralateral ACL lesion. There was no difference between the chance of re-injury after AM technique and the chance of contralateral ACL lesion (native ligament) with any technique.

Applications

The increased risk of graft re-rupture observed in anatomical reconstructions could in fact represent an approximation to the "normal knee" ACL rupture risk, that could be represented by the risk of contralateral knee lesion. The lower graft failure rates found in TT reconstruction could be because the neoligament simply is not submitted to the physiological forces that occur in the "normal" knee. With that in mind, one could speculate that it is not the AM technique that presents a higher failure rate, but it is the TT graft failure rate that is lower than it should be, probably due to incorrect femoral positioning.

Terminology

Transtibial technique refers to an anterior cruciate ligament reconstruction technique in which the femoral tunnel is created with a drill inserted through a tibial tunnel previously drilled. It leads to a non-anatomic positioning of the femoral tunnel, searching for an isometric position of the femoral tunnel. In the anteromedial portal technique, the femoral tunnel is created with a drill inserted through the arthroscopic anteromedial portal, which makes it possible to create the femoral tunnel in its anatomic position.

Peer-review

This is a very nice paper, it is well written with very interesting results and conclusions.

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Open wound management of esophagocutaneous fistula in unstable cervical spine after corpectomy and multilevel laminectomy: A case report and review of the literature

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Abstract

A 67-year-old female patient developed an esophagocutaneous fistula 4 mo after C4 and C5 partial corpectomy. Plain radiograph and computed tomography (CT) scan of cervical spine showed inferior screws pullout with plate migration that caused the esophageal perforation. Management included removal of anterior hardware, revision C4-5 corpectomy, iliac crest strut autograft and halo orthosis immobilization. The fistula was treated using antibiotics and a 10-french gauge rubber tube for daily irrigation and Penrose drain. At 3 mo, the esophagocutaneous fistula healed and the patient resumed oral feeding. Six months follow-up CT scan showed sound fusion with graft incorporation. At two-year follow-up, patient denied any neck pain or dysphagia. This case report presents a successful outcome of a conservative open wound management without attempted repair. The importance of this case report is to highlight this treatment method that may be considered in such a rare complication particularly if surgical repair failed.

Key words: Wound management; Esophagocutaneous fistula

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Core tip: Esophageal perforation and subsequent fistulization is a known complication following anterior cervical spine surgery. As part of the treatment of this complication, hardware removal is commonly required. The majority of the literature advises against conservative treatment of esophageal injury due to the associated morbidity and mortality.

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INTRODUCTION

Anterior cervical spine discectomy and corpectomy are reliable with good outcomes for the treatment of neck pain with radiculopathy or myelopathy. The incidence of esophageal perforation in anterior cervical spine surgery is 0.2% to 0.4%. High mortality rates up to 20% have been reported with injury even when the patient is treated within the first 24 h. This increases to 50% when treatment is further delayed. In rare circumstances with delayed diagnosis, esophagocutaneous fistulous tract may form and presents with discharge of food particles from the surgical wound. As with most infections involving orthopedic implants, management involves hardware removal, debridement of soft tissues and culture specific antibiotic^[1-4]. The objective of this case report is to present a successful open wound management without attempted repair of a patient with an esophagocutaneous fistula.

CASE REPORT

A 67-year-old female patient was hospitalized at the authors' institution for left distal femur fracture that was treated with open reduction and internal fixation. During her postoperative stay, it was noted that food particles were draining from an anterior cervical wound. Patient had a history of two previous cervical spine surgeries, both performed at other institutions. The first was a C4-6 posterior laminectomy without fusion, performed eight years prior to this hospitalization. The second surgery was performed 4 mo prior to her admission to the authors' institution. It consisted of C4 and C5 partial corpectomy with insertion of a polyetheretherketone (PEEK) cage and C3-6 anterior cervical instrumentation.

The spine service was consulted and plain radiograph demonstrated inferior screws pullout with plate migration (Figure 1). Computed tomography (CT) scan showed subcutaneous air tracking along the neck soft tissues. General surgery and otolaryngology were consulted and an esophagram (Figure 2) revealed ingested oral contrast tracking along the right subcutaneous tissues of the neck confirming perforation of the esophagus at the level of the inferior screws with fistulization through the anterior surgical wound. Blood work showed normal white cell count 8000 (normal 4500-10000), decreased prealbumin 6.1 mg/dL (normal 17-34) and serum iron level 15 mg/dL (normal 50-212) that confirmed malnutrition.

The patient's oral intake was suspended and a

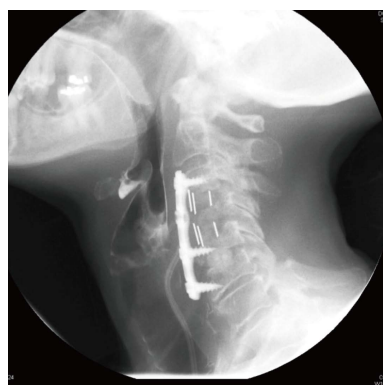


Figure 1 Lateral plain radiograph showed inferior screws pullout and anterior displacement of the plate.

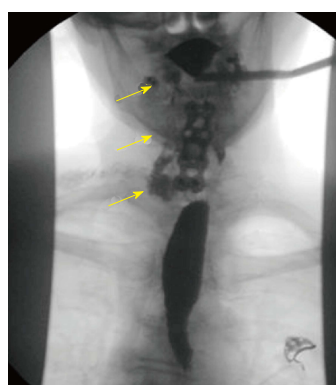


Figure 2 Anteroposterior fluoroscopic image of esophagram showed extravasated contrast material tracking along the right side of the neck (arrows).

nasogastric tube placed to facilitate feeding. The patient was taken to the operating room and underwent removal of the anterior hardware, drainage of cervical abscess, revision C4-5 corpectomy, C3-C6 fusion using tricortical iliac crest strut autograft and halo vest immobilization. The wound was left open and managed by the general surgery and otolaryngology services. One week after the revision cervical fusion, the patient was taken to the operating room by general surgery for irrigation and debridement, insertion of a 10 French gauge rubber tube for irrigation and Penrose drain. The wound was irrigated *via* the rubber tube two times daily with a dilute hydrogen peroxide solution. The patient was placed on ceftriaxone and flagyl for 6 wk as cultures grew polymicrobial mouth flora.

The halo vest removed at 3 mo. The fistulous tract healed at 3 mo and patient resumed oral feeding. Six months follow-up CT scan showed graft incorporation (Figure 3). At two years follow up, patient denied any neck pain or dysphagia and plain radiograph showed maintenance of the cervical spine alignment (Figure 4).

DISCUSSION

The incidence of esophageal perforation after anterior cervical spine surgery is 0.2% to 0.4% and may present

Table 1 Cases reported in the literature

Ref.	No of patients with perforation	Time of diagnosis	Management	Outcome
Zhong <i>et al</i> ^[11]	6	Early postoperative	Wound debrided in 3 patients, implant removed and primary suture of perforation in 2 patients	5 healed 1 died due to pneumonia
Ardon <i>et al</i> ^[3]	4	Early postoperative in 3 patients	Hardware removed with primary suture of the perforation in 2 patients and in one of these an additional sternocleidomastoid myoplasty was done	3 healed 1 patient died due to systemic complication, indirectly related to the perforation
Yin <i>et al</i> ^[4]	1	3 yr after surgery	Emergency tracheostomy, hardware removal, abscess drainage and infected tissue debridement	Healed
Jamjoom <i>et al</i> ^[2]	1	Early postoperative	No definite perforation detected at reoperation, pharyngocutaneous fistula formed subsequently No attempted repair Open drainage in association with broad spectrum antibiotics, continuous nasopharyngeal suctioning, stopping of oral intake and gastrostomy feeding	Fistula recurred twice soon after resumption of oral feeding
Orlando <i>et al</i> ^[9]	5	2 during surgery 2 early postoperative 6 mo postoperative in 1	Hardware removal in 2 Hardware retained in 1 No hardware inserted in 2 Esophagus repaired in 4	All healed
Sun <i>et al</i> ^[10]	5	1 during surgery 4 early postoperative	Hardware removal in 2 Esophagus repaired in 4 reinforcement with a sternocleidomastoid muscle flap in 1 patient	All healed
Balmaseda <i>et al</i> ^[20]	1	Early postoperative	Hardware retained No repair	Healed
Ji <i>et al</i> ^[21]	1	Early postoperative	Hardware retained repaired and reinforced with sternocleidomastoid flap Recurrent esophageal leakage 2 d after the repair Wound reopened and a continuous irrigation and drainage system used	Healed

**Figure 3** Computed tomography scan sagittal reformat showed incorporation of the iliac crest strut graft.**Figure 4** Lateral cervical spine plain radiograph at 2-year follow-up showed incorporation of the iliac crest strut graft with maintenance of the cervical spine alignment.

intraoperatively or in the postoperative period^[1-5]. Graft dislodgment, prominent hardware or migration can result in chronic pressure on the esophagus, which leads to ischemic tissue breakdown^[4,6,7]. It has been reported that 50% of esophageal fistulas occur at C5-6 level instrumentation. At this anatomic landmark, known as Lannier's triangle, the pharynx transitions to the esophagus and the posterior esophageal mucosa is extremely thin and covered only by fascia^[8-11].

Patients with delayed esophageal injury commonly present with surgical wound infection, odynophagia (pain

on swallowing) and dysphagia^[1,4,12,13]. When esophageal injury is suspected, contrast swallow studies may reveal extravasation of the contrast material and CT scan may demonstrate subcutaneous air. The patient in the current report had loose hardware, prior corpectomy and presented with food particles draining from an anterior cervical wound, which is pathognomonic for esophageal fistula.

Treatment strategies for esophageal perforation and fistula are debated (Table 1). The majority of

publications recommended surgical repair of esophageal injury due to the associated morbidity and mortality^[1,3,4,7,9,10,14-19]. However, some have reported successful conservative management^[20,21]. The key aspects of the treatment strategy include: Anterior hardware removal, posterior fusion for patients in whom primary fusion has not yet occurred, primary closure of the esophageal perforation, and intravenous antibiotics. The patient in the current report was treated with anterior hardware removal and revision interbody fusion with iliac crest tricortical autograft. Patient's prior multilevel laminectomy rendered the cervical spine unstable after anterior hardware removal. In the setting of esophageal perforation and active infection re-instrumentation of the anterior cervical spine was not possible. Commonly a posterior cervical instrumentation and fusion would be the approach considered. The patient presented in the current study had an increased risk of postoperative posterior cervical spine surgical wound infection related to the existing anterior wound infection and malnutrition. Furthermore, the previous multilevel wide posterior laminectomy would have made the posterior cervical approach challenging with increased risk of dural tear and spinal cord injury. Given those risks associated with a posterior approach in this patient, the authors opted to use a halo vest immobilization postoperatively for cervical stabilization in place of posterior instrumentation. The esophageal perforation and fistulous tract in this patient successfully resolved without attempted repair by two times daily wound irrigation through a rubber tubing and Penrose drain.

In conclusion, the current report shows that this complication can be successfully treated with open wound management. This highlights the value of wound management for such a rare complication that could be considered after failed surgical repair of esophageal injury.

COMMENTS

Case characteristics

A 67-year-old female patient presented with food particles draining from an anterior cervical wound. Patient had a history of two previous cervical spine surgeries; the first was a C4-6 posterior laminectomy without fusion, performed eight years prior current presentation. The second surgery was performed 4 mo prior to her admission to the authors' institution. It consisted of C4 and C5 partial corpectomy with insertion of a PEEK cage and C3-6 anterior cervical instrumentation.

Clinical diagnosis

Esophagus perforation with fistulization through the anterior surgical wound.

Laboratory diagnosis

Blood work showed normal white cell count 8000 (normal 4500-10000), decreased prealbumin 6.1 mg/dL (normal 17-34) and serum iron level 15 mcg/dL (normal 50-212) that confirmed malnutrition.

Imaging diagnosis

Plain radiograph demonstrated inferior screws pullout with plate migration.

Computed tomography (CT) scan showed subcutaneous air tracking along the neck soft tissues. Esophagram revealed ingested oral contrast tracking along the right subcutaneous tissues of the neck.

Treatment

Management included suspended oral intake, a nasogastric tube feeding, removal of anterior hardware, revision C4-5 corpectomy, iliac crest strut autograft and halo orthosis immobilization. The wound left opened and a 10-french gauge rubber tube was placed for daily irrigation. The patient was placed on ceftriaxone and flagyl for 6 wk.

Related reports

The majority of publications recommended surgical repair of esophageal injury due to the associated morbidity and mortality. However, some have reported successful conservative management.

Term explanation

Fifty percent of esophageal fistulas occur at C5-6 level instrumentation. At this anatomic landmark, known as Lannier's triangle, the pharynx transitions to the esophagus and the posterior esophageal mucosa is extremely thin and covered only by fascia.

Experiences and lessons

When esophageal injury is suspected, contrast swallow studies may reveal extravasation of the contrast material and CT scan may demonstrate subcutaneous air. The current report shows that this complication can be successfully treated with open wound management.

Peer-review

Text well written and easily comprehensible with clear figures.

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Bennett's fracture associated with fracture of Trapezium - A rare injury of first carpo-metacarpal joint

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Abstract

Association of fracture of trapezium with Bennett's

fracture is very rare and makes reduction and stabilisation more difficult. We are reporting a rare case of Bennett's fracture with fracture of the trapezium and subluxation of the carpo-metacarpal joint (CMC) joint. The patient was a 47-year-old school teacher who fell from his motorbike on his outstretched right dominant hand. Radiographs and computed tomography showed fracture of the trapezium with subluxation of the CMC joint, associated with Bennett's fracture. Open reduction and internal fixation was carried out. Trapezium was reduced first and secured with a 2 mm diameter screw. Bennett's fracture was then reduced and fixed with two per-cutaneously placed Kirchner's wires. CMC was stabilised with per-cutaneous Kirchner's wires. Latest follow up at 12 mo showed a healed fracture with good reduction of the CMC joint. Clinically patient had no pain and normal extension, abduction and opposition of the thumb. QuickDASH score was 3.9/100. Thus, fracture of trapezium associated with a Bennett's fracture is a rare injury and if ignored it may lead to poor results. This injury is more challenging to manage than an isolated Bennett's fracture as anatomical reduction of the trapezium with reduction of the first CMC is needed. Fracture of the trapezium should be fixed first as this will provide a stable base for reduction of the Bennett's fracture.

Key words: Bennett's fracture; Carpo-metacarpal joint; Trapezium

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Core tip: Association of fracture of the trapezium with Bennett's fracture is very rare and makes reduction and stabilisation more difficult. We are reporting a rare case of Bennett's fracture with fracture of the trapezium and subluxation of the carpo-metacarpal joint (CMC) joint, and describing a technique for successful reduction and stabilisation of these fractures. Trapezium should be reduced first and secured with a 2 mm diameter screw. Bennett's fracture should then be reduced and fixed with two per-cutaneously placed Kirchner's wires. CMC should

be stabilised with per-cutaneous Kirchner's wires. This is expected to result in good functional outcomes.

Goyal T. Bennett's fracture associated with fracture of Trapezium - A rare injury of first carpo-metacarpal joint. *World J Orthop* 2017; 8(8): 656-659 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v8/i8/656.htm> DOI: <http://dx.doi.org/10.5312/wjo.v8.i8.656>

INTRODUCTION

Bennett's fracture typically involves an intra-articular fracture of the base of the first metacarpal with dislocation of the carpo-metacarpal joint (CMC). This represents avulsion of the attachment of the volar oblique ligament. Most common mechanism is fall on hand with thumb in abduction or extension. Fractures of the trapezium are rare and accounts for only 3%-5% of carpal fractures^[1,2]. Association of fracture of trapezium with a Bennett's fracture is very rare. Presence of fracture of trapezium makes reduction and stabilisation of the Bennett's fracture more challenging. High degree of clinical suspicion is necessary as CMC injuries may be a result of indirect force resulting in little swelling^[3]. Neglected or untreated injuries may lead to degenerative changes of the CMC joint resulting in pain during grip and pinch.

We are reporting a case of Bennett's fracture with fracture of the trapezium and disruption of CMC joint. This is an extremely rare injury and only a few cases have been mentioned in literature before^[4-7]. Open reduction and internal fixation was carried out and clinical and radiological outcomes were good at 6 mo of follow up.

CASE REPORT

The patient was a 47-year-old school teacher who fell from his motorbike on his outstretched right hand. He was right hand dominant. Radiographs showed fracture of the trapezium with subluxation of the CMC joint, associated with Bennett's fracture (Figure 1).

Patient was operated five days after the injury under general anaesthesia. Fracture site was approached using a curved incision beginning at the dorso-radial border of the first metacarpal bone, curving along the junction of the palmar and dorsal skin, to the distal wrist crease. Base of the first metacarpal was recognised which helped in identification of the CMC joint and the trapezium. Trapezium was reduced first and secured with a 0.045-inch Kirchner wire (Figure 2). A 2 mm diameter screw was used to secure the fracture. Bennett's fracture was reduced and fixed with two per-cutaneously inserted 0.045-inch Kirchner's wires (Figure 3). The CMC joint was further stabilised with a per-cutaneously inserted 0.045-inch Kirchner's



Figure 1 Preoperative radiograph showing the Bennett's fracture with fracture of the trapezium.



Figure 2 Intraoperative photograph showing the surgical approach, fixation of the capitulum with screw and reduction of the carpo-metacarpal joint.

wire. Limb was put in a thumb spica cast.

Sutures were removed at 10 d followed by removal of Kirchner wires at 3 wk. Cast was continued for a total of 8 wk after the surgery. Range of motion and gripping exercises were begun after the cast was removed.

Latest follow up at 12 mo showed no fracture lines, with good reduction of the CMC joint. Clinically patient had no pain and normal extension, abduction and opposition of the thumb (Figure 4). Stress testing of the CMC revealed normal ligaments. QuickDASH score was 3.9/100^[8].

DISCUSSION

Most probable mechanism of Bennett's fracture with fracture of the trapezium is axial loading of a partially flexed metacarpal bone. Axial loading in a flexed thumb may initially result in a Bennett's type fracture due to bony avulsion of the anterior oblique ligament. This Bennett's fragment represents the ulnar-volar part of the base of the metacarpal and has strong capsulo-ligamentous attachments. If the Bennett's fragment is small and axial loading continues, trapezium will be impacted between the remaining part of metacarpal base and the radial styloid resulting in a vertically split or

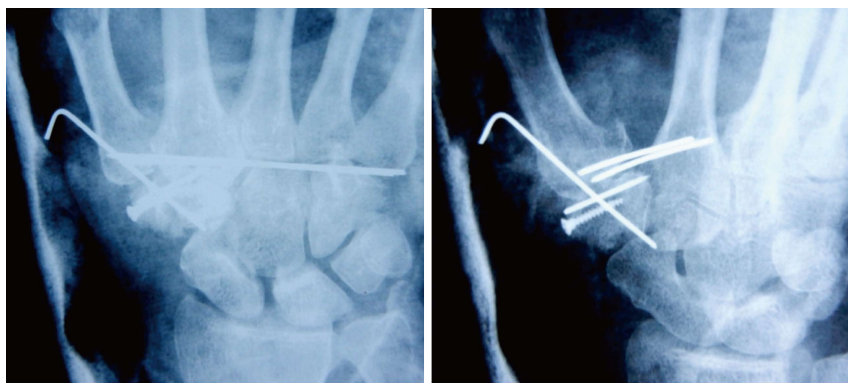


Figure 3 Postoperative radiograph showing reduction of fracture fragments and the carpo-metacarpal joint.



Figure 4 Clinico-radiological follow-up at 6 mo. A: Radiograph at 6 mo follow up showing a healed fracture with maintainance of joint reduction; B: Clinical photograph showing good range of motion.

comminuted fracture of the trapezium. An alternative mechanism of injury could be a hyper-abduction shearing force on the first web-space. This can be seen commonly if a person suffers deceleration injury while holding a handlebar, resulting a commissural shearing force on the first web-space. This may also occur if a person falls on the radial side of the hand with thumb in abduction, so that the first web-space suffers a commissural force.

Stable reduction of the CMC joint and restoring congruity of the articular surface is the goal of treatment^[9,10]. Residual subluxation of the joint or intra-articular displacement of more than 4 mm may lead to poor functional outcomes^[11].

Fractures of carpal bones of hand, and subluxations

of CMCs may be overlooked as soft tissue injuries unless specifically looked for. This will result in poor functional outcomes in long-term follow-up. The type of views imaged or quality of the radiographs may frequently contribute to a missed diagnosis. Appropriate true antero-posterior and lateral radiographs of CMC joint should be insisted. Special views such as Bett view is useful, in which the hand is pronated approximately 20°-30° and the imaging beam is directed obliquely at 15° in a distal to proximal direction, centered over the trapeziometacarpal joint. Computed tomography is a useful imaging modality to study complex fractures of the hand and provides better anatomical details.

Injuries to the CMC joint should be carefully searched

for in patients with intra-articular fractures of the trapezium. These may be associated with the Bennett's fracture, as in this case, or with purely ligamentous injury to the CMC joint. McGuigan and Culp reported 11 patients with intra-articular fractures of the trapezium, four of which were associated with the Bennett's fracture^[4]. Three of these fractures were initially unnoticed. All these patients had good clinical outcomes with open reduction and internal fixation in terms of range of motion, pain and patient satisfaction.

In this case the Bennett's fracture was associated with the vertically split fracture of the trapezium. These fractures require open reduction and internal fixation in order to control reduction of both these fractures. The fracture of trapezium was fixed first with a K wire and a screw to provide a stable platform for reduction of the Bennett's fracture. Bennett's fracture was then fixed with K wires. This gave excellent results at follow up.

Thus, fracture of trapezium associated with a Bennett's fracture is a rare injury and if ignored it may lead to poor results. Fracture of the trapezium should be fixed first as this will provide a stable base for reduction of the Bennett's fracture.

COMMENTS

Case characteristics

This was a rare case of carpal injuries.

Clinical diagnosis

Bennett's fracture dislocation with fracture of Trapezium.

Differential diagnosis

Bennett's fracture dislocation.

Imaging diagnosis

Plain radiographs and computed tomography scan confirmed the diagnosis

Treatment

The fracture of trapezium was fixed first with a K wire and a screw to provide a stable platform for reduction of the Bennett's fracture which was then fixed with K wires.

Experiences and lessons

This is a rare injury and if missed may make the reduction and stabilisation of Bennett's fracture dislocation difficult.

Peer-review

This is generally a good paper.

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