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REVIEW

Orthopaedic care provided by the 14th combat support hospital in support of humanitarian and disaster relief after hurricane Maria in Puerto Rico

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Abstract

On September 20, 2017 Hurricane Maria, a category 4 hurricane, made landfall on the eastern coast of Puerto Rico. This was preceded by Hurricane Irma, a category 5 hurricane, which passed just off the coast 13 d prior. The destruction from both Hurricane Irma and Maria precipitated a coordinated federal response which included the Federal Emergency Management Agency (FEMA) and the United States military. The United States Army dispatched the 14th Combat Support Hospital (CSH) to Humacao, a city on the eastern side of the island where Maria made landfall. The mission of the 14th CSH was to provide medical humanitarian aid and conduct disaster relief operations in support of the government of Puerto Rico and FEMA. During the 14th CSH deployment to Puerto Rico, 1157 patients were evaluated and treated. Fifty-seven operative cases were performed to include 23 orthopaedic cases. The mean age of the orthopaedic patients treated was 45.7 years (range 13-76 years). The most common operation was irrigation and debridement of open contaminated and/or infected wounds. Patients presented a mean 10.8 d from their initial injury (range 1-40 d). Fractures and infections were the most common diagnoses with the greatest delay in treatment from the initial date of injury. The deployment of the 14th CSH to Puerto Rico was unique in its use of air transport, language and local customs encountered, as well as deployment to a location outside the continental United States. These factors coupled with the need for rapid deployment of the 14th CSH provided valuable experience which will undoubtedly enable future success in similar

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endeavors.

Key words: Hurricane Maria; Disaster relief; Combat support hospital; Army

Core tip: Health care providers embarking on humanitarian and disaster relief efforts should consider the following factors: What specific diagnoses or injuries can your team safely manage considering the knowledge, technical ability, equipment, and facilitates your team possesses? What was the health of the patient population pre-disaster and their access to quality health care? What can be done to help mitigate language and cultural barriers which make effective communication with patients difficult? What local providers and resources can be engaged to ensure continued care for patients after relief efforts have concluded?

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INTRODUCTION

On September 20, 2017 Hurricane Maria, a category 4 hurricane, made landfall on the eastern coast of Puerto Rico. This was preceded by Hurricane Irma, a category 5 hurricane, which passed just off the coast 13 d prior. The destruction which ensued precipitated a coordinated federal response which included the Federal Emergency Management Agency (FEMA) and the United States military. United States Army assets were mobilized to Puerto Rico to provide support in the form of personnel, food, drinking water, medicine, and military aircraft. In addition to providing immediate relief services, the United States Army dispatched the 14th Combat Support Hospital (CSH) to Humacao, a city on the eastern side of the island where Maria made landfall. The mission of the 14th CSH was to provide medical humanitarian aid and conduct disaster relief operations in support of the government of Puerto Rico and FEMA.

From October 6 through November 12, 2017, the 14th CSH provided medical and surgical services for the population of Humacao and surrounding region. The purpose of this paper is to describe the mission and capability of the 14th CSH, detail the operative care provided to orthopaedic patients, and provide lessons learned from the humanitarian and disaster relief operations conducted in Puerto Rico in response to Hurricane Maria.

BACKGROUND

The 14th CSH is one of several active duty combat support hospitals within the Army Medical Department. CSH's are an essential element within the echelons of care in battlefield medicine. A CSH affords the highest level of medical, surgical, and trauma care available within the combat zone. They possess modular configurations which allow commanders to tailor medical support to various operational environments. Specialists which can be assigned to a CSH include general surgeons, orthopaedic surgeons, thoracic surgeons, vascular surgeons, obstetrician/gynecologists, and urologic surgeons. In addition to laboratory and radiographic capabilities, CSH's also offer a blood blank and nutrition capabilities. The 44-bed CSH configuration can have up to 250 personnel, with two operating tables, 20 intensive care unit (ICU) beds, and 24 holding beds. Within combat environments, patients are typically held no longer than 72 h prior to evacuation to higher echelons of care[1].

While the primary mission of the 14th CSH is to provide the highest level of patient care within combat zones in support of conventional military operations, a secondary mission of the 14th CSH involves the Defense Support of Civil Authorities (DSCA). DSCA includes support provided by United States military forces, Department of

Defense (DOD) civilians, DOD contract personnel, DOD Component assets, and National Guard forces in response to requests from civil authorities for domestic emergencies within the continental United States, Alaska, Hawaii and United States territories. This support can involve law enforcement, certain domestic activities, or certain qualifying entities for special events[2]. Examples of prior United States military DSCA missions include: The response to Hurricane Katrina[3] in 2005 as well as hurricane Sandy[4] in 2012.

Given the scope and scale of destruction which resulted from Hurricane Maria, the 14th CSH was activated in support of its DCSA mission role. The operations of the 14th CSH were conducted out of the Humacao Arena, an 8000-seat building which was the home of a local professional basketball team. The structure suffered minimal damage and possessed its own generator with central air conditioning. It was also located within a few miles of the city's two main hospitals and was easily accessible by two major highways. A landing zone was set up immediately across from the arena in a large open field for air medical and transport operations. The 14th CSH operating room and radiology facilities were set up just outside the arena (Figure 1). The Emergency Medical Treatment section, Pharmacy, Laboratory, as well as inpatient wards were set up within the arena (Figure 2).

INTERVENTION

Patients presented to the CSH either by military or local civilian medical transport. The patients were then evaluated by triage nurses and physicians to ensure the patients could be effectively managed with the resources of the CSH. Patients necessitating resources beyond the capability of the CSH were transferred to other military or local medical facilities.

During the 14th CSH deployment to Puerto Rico, 1157 patients were evaluated and treated. Fifty-seven operative cases were performed to include 23 orthopaedic cases. The mean age of the orthopaedic patients treated was 45.7 years (range 13-76 years). The most common operation was irrigation and debridement of open contaminated and/or infected wounds (Table 1). Patients presented a mean 10.8 d from their initial injury (range 1-40 d). Fractures and infections were the most common diagnoses with the greatest delay in treatment from the initial date of injury (Table 1).

Patients were assessed pre-operatively by the Medicine and Anesthesia services. Mean the American Society of Anesthesiologists (ASA) scores were 2.3 (Table 1). Diabetes was the most common co-morbid diagnosis. Regional anesthesia was performed at the discretion of the Anesthesia Service after discussion with the operating physician. A total of 8 regional blocks were performed. All patients received pre-operative antibiotics. Intra-operative cultures, when obtained, were sent to a local hospital laboratory for processing. Intra-operative plain radiographs were performed with a portable unit which had a viewing station located just outside the operating room.

Five patients were discharged on the same day as their operation. Patients without risk factors for DVT and isolated lower extremity fractures were managed with 81 mg ASA twice daily for DVT prophylaxis as inpatients. One post-operative patient was transferred to another facility after his septic joint was irrigated and debrided for further evaluation and treatment given his multiple medical co-morbidities which necessitated a higher level of medical care. The remaining post-operative patients were discharged to their respective local residences with patient instructions, follow-up plans of care, medications, and dressing supplies if necessary.

Resorbable suture was used when 2 wk follow up went beyond the anticipated conclusion of CSH operations. In addition, patient follow-up and care coordination was made with local providers and other military medical assets. These included a local non-operative orthopaedist, the ambulatory clinic at Fort Buchanan, and the USNS Comfort. No immediate complications were observed however even immediate short term follow-up was limited. Mean follow-up with post-operative patients was 7.5 d (range 0-28 d).

CONCLUSION

This case series provides the first description of orthopaedic care provided by a CSH on a DSCA mission. The deployment of the 14th CSH to Puerto Rico was unique for many reasons. These included: Use of air transport, language and local customs encountered, as well as deployment to a location outside the continental United States. These factors coupled with the need for rapid deployment of the 14th CSH

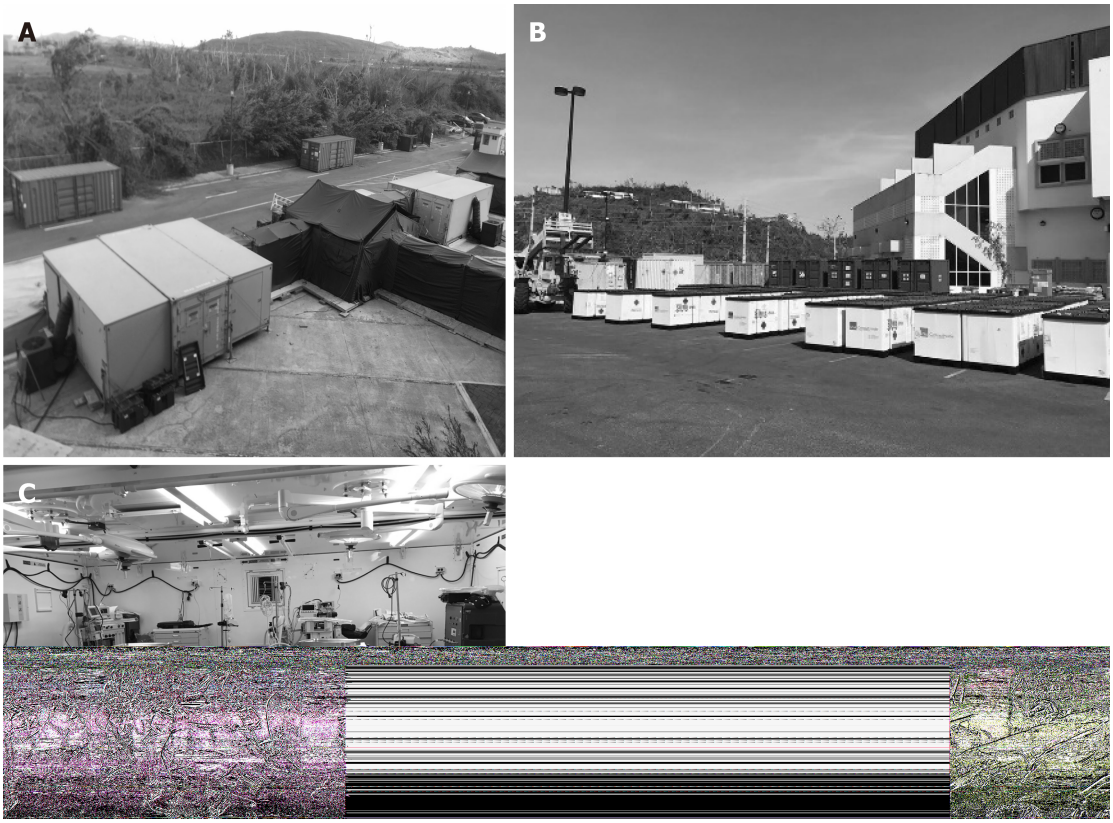

Figure 1 The 14th Combat Support Hospital operating room and radiology facilities were set up just outside the arena. A: 14th Combat Support Hospital operating and radiology mobile units; B: 14th Combat Support Hospital operating and radiology mobile units along with storage containers and supplies staged outside the arena; C: Operating room with two table set-up.

provided valuable experience which will undoubtedly enable future success in similar endeavors.

Another unique element of the 14th CSH relief efforts was its direct collaboration with Disaster Medical Assistance Teams (DMAT). A DMAT is a trained, mobile, self-contained, self-sufficient, multidisciplinary medical team that can respond rapidly after a disaster (48 to 72 h) to provide medical treatment to an affected area. The team can include physicians, nurses, pharmacists, paramedics, and EMTs. DMATs fall under the National Disaster Medical System (NDMS), a federally coordinated system with the United States Department of Health and Human Services[5]. Multiple DMATs assisted the 14th CSH efforts for 2 weeks at a time and were an important part of the triage and treatment of the local population. These teams operated out of the same location and used the same facilities as the 14th CSH.

Shortly after the 14th CSH became operational, representatives from the 14th CSH contacted local hospitals to assist with helping these facilities become more operational. This included coordinating the request and delivery of needed supplies such as tarps and generator equipment. In addition, the 14th CSH engaged local and regional government to help with delivery of food and water to local organizations and churches for distribution.

Within the Humacao area, the 14th CSH was able to locate only one practicing orthopaedic surgeon who was working part-time as a non-operative provider. This led to challenges with coordinating care for patients in anticipation of the 14th CSH's departure. In addition, patients faced challenges with access to orthopaedic surgeons outside of the Humacao area due to overburdened hospitals as well as underinsurance and/or no insurance. This left a large patient population within the Humacao region in need of orthopaedic services. Many of the patients presenting for orthopaedic care had delayed presentations which made treatment more difficult. This included patients presenting with malunited fractures and sub-acute infections. Other challenges included adverse effects of weather on facilities and equipment which included power outages, loss of climate control in the operating room and patient wards, and water leakage into the operating room and equipment/supply areas. The operating room did not possess a viewing station for digitally captured radiographs which made viewing intra-operative radiographs challenging.

Similar challenges have been described by other authors in disaster relief efforts.

Figure 2 The Emergency Medical Treatment section, Pharmacy, Laboratory, as well as inpatient wards were set up within the arena. A: Emergency Medical Treatment, Intensive Care Unit and Intermediate Care Ward sections arranged around the periphery of the arena. The central portion of the arena was used for storage of equipment and supplies; B: Intensive Care Unit section and associated equipment. There were two 20 bed Intensive Care Unit sections, one 10 bed Emergency Medical Treatment section, and one 20 bed Intermediate Care Ward section.

Sechriest *et al*[6] characterized the orthopaedic care provided on the USNS Mercy after the 2004 Asian Tsunami as "challenging at every level". This involved patient deconditioning and/or poor physical health, chronic and complex injuries and conditions, and lack of timely follow-up by physicians with orthopaedic expertise in the post-disaster region. In addition, the authors describe communication with patients and their families as perhaps the single greatest challenge faced by the providers. Despite interpreters from the host nation, language and cultural barriers presented difficulties in gathering accurate histories, obtaining informed consent, and communicating post-operative expectations and plans for continued care. Beitler *et al*[7] cited one of the greatest challenges for the 48th CSH, during Operation Enduring Freedom in Afghanistan, was maintaining the balance between capabilities and requirements. In providing care to Afghan and United States contractors, the pediatric and more elderly patients which were treated frequently required advanced ICU care followed by rehabilitation. Patients evacuated to the 48th CSH because of limited local medical infrastructure led to significant challenges with respect to discharge planning, transport, and placement. Born *et al*[8] describe lack of systems interface as a recurrent problem in disaster response and note that during the 2005 Hurricane Katrina relief effort, no communication existed between government and/or military responders for several days. Due to flooding and power outages, medical facilities were isolated, which allowed for little command and control as well as limited contact with the relief efforts surrounding them. The authors also describe challenges faced by the USNS Comfort during the 2010 Haiti Earthquake which included access to a single C-arm as well as a limited supply of orthopaedic implants.

Despite experiencing many similar challenges, the 14th CSH was able to provide orthopaedic care to residents within the Humacao region and performed nearly two dozen orthopaedic cases. Although follow-up was very limited, there were no immediate complications. In all cases, management was guided by the principle of "primum non nocere" (first do no harm). Additional objectives focused on operative intervention which required limited ancillary support and follow-up. Comprehensive work-up and treatment was performed by a multi-disciplinary team comprised of specialists in nutrition, pharmacy, medicine, anesthesia, and surgery in order to optimize patients peri-operatively.

As an essential element within the echelons of care in battlefield medicine with equipment and personnel typically configured for combat zones, the 14th CSH primarily possessed capability for damage control intervention with less capacity for the subacute and ambulatory patients which presented during the relief effort. When fixation was performed it was most often definitive fixation with small fragment or mini-fragment plates and screws. Percutaneous K-wire fixation was also utilized in a few cases in the hand and upper extremity. One case necessitated the shipment of implants to the CSH. In addition, capability for definitive management for subacute and ambulatory patients was also limited due to a lack of fluoroscopy and a radiolucent operating table.

This case series illustrates the unique capabilities of the CSH and as well as the orthopaedic conditions encountered the hurricane Maria disaster relief effort. It also highlighted challenges of providing care to patients with limited resources and uncertain follow-up care. Future similar efforts will undoubtedly benefit from the experience gained and lessons learned by the 14th CSH's deployment to Puerto Rico.

Table 1 Summary of the patients included in series

Sex	Age (yr)	Diagnosis	ASA	Time from injury (d)	Operative treatment
M	56	Foreign body	3	3	Foreign body excision/I&D
F	26	Complex elbow dislocation	1	1	CR splinting
M	13	BBFF	1	1	CR splinting
M	42	BBFF	3	40	ORIF
F	25	Humerus fx	2	2	CR splinting
M	14	Radial shaft fx	1	1	ORIF
F	71	Patella fx	2	1	ORIF
M	76	Flexortenosynovitis	3	35	Amputation
F	41	Trimal ankle fx	2	40	CR splinting
M	66	Crush injury digit	1	2	CRPP, nailbed repair
M	52	Open 5th MC fx[1]	4	1	I&D, 5th ray resection
M	47	Pre-patella septic bursitis/septic knee[2]	3	28	I&D
M	26	DRF with acute CTS	2	2	ORIF, CTR
F	68	Bimal ankle fx	4	1	ORIF
M	63	Patella fx	1	4	ORIF
M	36	Crush injury digit	2	1	Nailbed repair
M	27	Ulna shaft fx	1	2	ORIF
M	51	Distal biceps rupture	2	24	Open repair
	45.7[3]		2.3[3]	10.8[3]	

[1]Three prior irrigation and debridements;
[2]Prior pre-patella septic bursitis and septic knee irrigation and debridement;
[3]Mean value. BBFF: Both bone forearm fracture; fx: Fracture; CR: Closed reduction; I&D: Irrigation and debridement; ORIF: Open reduction internal fixation; DRF: Distal radius fracture; CTS: Carpal tunnel syndrome; CTR: Carpal tunnel release; ASA: The American Society of Anesthesiologists.

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MINIREVIEWS

Revision total hip arthroplasty: An analysis of the quality and readability of information on the internet

Gerard Anthony Sheridan, Carl O'Brien, Bassam A Masri, Clive P Duncan, Donald S Garbuz

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Author contributions: Sheridan GA designed the research, performed the research, analyzed the data, and wrote the paper; O'Brien C collected data and analyzed data; Masri BA analyzed the data and wrote the paper; Duncan CP contributed to the writing of the paper; Garbuz DS designed the research and wrote the paper.

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Abstract

The demand for revision total hip arthroplasty (THA) is increasing. Information quality on the internet has been extensively analysed in relation to primary THA but no such analysis has ever been performed for revision THA. Our aim was to assess the quality and readability of this information. Three major internet search engines were searched for information on revision THA. All websites were assessed for quality of information using the DISCERN score, the Journal of the American Medical Association benchmark criteria and a novel scoring system specific to revision THA [Vancouver Revision Arthroplasty Information (VRAI) score]. Website readability was assessed, as was presence of the Health On the Net Foundation (HON) seal. The majority of websites (52%) were academic with a post-graduate reading level. Only 6.5% of websites had the HON seal. Twenty-eight percent of websites had a 'good' DISCERN score and only 28% had a 'good' score with the novel VRAI scoring system. Health information websites had significantly higher rates of 'good' VRAI scores (P = 0.008). Websites with the HON seal had significantly higher DISCERN scores (P = 0.01). All governmental websites were at a reading level suitable for patient review. Information on the internet relating to revision THA is of low quality, much lower than the quality of information on primary THA. We recommend governmental websites for their readability and health information websites for their quality of information specific to revision THA. Websites with the HON seal provide higher quality information and should be recommended to patients as reading material regarding revision THA.

Key words: Revision; Hip; Arthroplasty; Internet; Quality; Readability

Core tip: Information related to revision total hip arthroplasty (THA) on the internet is of generally poor quality and seems to be of lower quality than information relating to primary THA on the internet. Only 28% of websites had 'good' quality information as

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determined by both the validated DISCERN score and the novel revision THA-specific Vancouver Revision Arthroplasty Information score. We recommend that patients use governmental websites as these are the most readable on the internet. We also recommend the use of health information websites as these were of the highest quality overall. Academic websites should be avoided as sources of patient information given their advanced readability and overall lack of patient-relevant content relating to revision THA.

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INTRODUCTION

Revision total hip arthroplasty (THA) is a commonly performed procedure in orthopaedic practice. The commonest indications for revision THA in modern practice are aseptic loosening, osteolysis and instability[1]. Numerous sources have projected a significant international increase in the demand for this procedure both in Europe and in the United States by the year 2030[2,3]. With the rise in demand for revision THA, we can expect that patients will increasingly reference the internet for sources of information relating to this procedure. Extensive research has already been conducted to assess the quality of internet-based information relating to primary THA[4-7]. However, no such analysis has been conducted to assess the quality of information relating to revision THA. The aim of this study is to assess sources of information on the internet relating to revision THA for quality and readability using a number of validated scoring systems, a novel scoring system and statistical analysis.

METHODS

Google, Yahoo!, and Bing search engines were used to browse the internet for the terms 'Revision', 'Hip', 'Arthroplasty', and 'Replacement'. The search took place on August 29, 2018 at 23.30. Given the 72.68% majority market share of Google, we analysed the first 40 websites returned by the Google search[8]. We then analysed the first 20 websites returned by the smaller search engines on both Bing and Yahoo!. Any website duplicates were excluded from the analysis. All the websites that were reviewed are listed in Supplement Table 1.

All websites were reviewed within 2 wk of the original search by two of the named authors. Each website was allocated to one of the following categories: Academic, commercial, physician, allied-health, media-related, health information website, social/discussion page, governmental, non-profit organisations, and unspecified. These categories have already been regularly used in the literature for assessing information quality on the internet[4,9,10]. Each website was then analysed against a number of scoring systems to assess the quality of the information pertaining to revision hip arthroplasty within.

Each website was assessed for the presence of a 'Health On the Net Foundation' (HON) seal. The HON seal originated in Geneva, Switzerland in 1995 at the conference entitled 'The Use of the Internet and World-Wide Web for Telematics in Healthcare'[11]. In an attempt to provide laypeople and medical professionals with reliable sources of healthcare information, this seal was developed for websites that provided users with high quality information.

The next assessment involved the DISCERN tool, as described by Charnock *et al*[12] in 1999. It comprises 8 questions on reliability, 7 on treatment information and a final question on overall website quality. The maximum score is 80 and a score of greater than 70 is classified as 'excellent' while a score of greater than 50 is considered to be 'good'.

The authors developed a novel scoring system to specifically assess the quality and relevance of information regarding revision THA provided on these websites. This 20-point scoring system assesses whether the website addresses the essential preoperative (6 points), perioperative (7 points) and postoperative (7 points) factors

Table 1 A novel scoring system

Vancouver Revision Arthroplasty Information score (1 point per topic covered)
Preoperative
Indications
Symptoms
Timing after primary
Investigations preoperatively
Joint aspiration preoperatively
Imaging preoperatively
Perioperative
Surgical options
2-stage revision
Single-stage revision
Implant types
Length of surgery
Length of hospital stay
Rehabilitation
Postoperative
Venous thromboembolism
Infection
Dislocation
Fracture
Limb length discrepancy
Nerve injury
Mortality

that patients and healthcare professionals should be aware of when reading information relating to revision THA (Table 1). This score was entitled the 'Vancouver Revision Arthroplasty Information' (VRAI) score. A VRAI score of 12 was considered to be 'good' and a score of 16 was considered 'excellent'.

The interobserver variability was evaluated for both the DISCERN score and the novel VRAI score using Cohen's kappa co-efficient (κ). This coefficient was described by Cohen in 1960 and has been utilised since then to measure agreement levels between observers for a large range of scoring systems[13]. The below equation demonstrates how Kappa was evaluated, where Po is the observed agreement among raters and Pε is the probability of agreement by chance. When κ = 1, there is complete agreement between the observers: $\kappa = (Po - P\varepsilon)/(1 - P\varepsilon)$.

A Kappa value of 0 implies that the scores have no similarity and can be explained by chance. A negative Kappa value implies that the interobserver agreement is worse than what would be expected to occur at random. A good level of agreement determined by the κ ratio is greater than 0.6. Greater than 0.4 is considered to be a moderate level of agreement. Greater than 0.2 is fair and less than 0.2 is poor. Excellent agreement correlates with a κ value above 0.8.

All websites were then assessed using the Journal of the American Medical Association (JAMA) benchmark criteria. These criteria include 4 parameters: Authorship, attributions, affiliations and credentials[14]. It was noted specifically which criteria were fulfilled and which criteria were not. 'Authorship' is important in allowing the reader to identify the origin of the information. 'Attribution' deals with content referencing. 'Affiliation' addresses any potential conflict of interest an author might have and 'currency' addresses whether or not the content is current and therefore relevant to the reader.

Finally, every website for inclusion in the study was assessed using the 'Flesch reading-ease' test. We defined the readability of each website according to the school grade that the content would be most compatible with. The score was as follows: 5th grade, 6th grade, 7th grade, 8th & 9th grade, 10th-12th grade, college student, and postgraduate.

Statistical analysis was performed using STATA© software [Stata/IC 13.1 for Mac (64-bit Intel)]. Fisher's exact test was used to analyse whether the website type was significantly related to presence of the HON seal and to assess whether the website

type was also predictive of a 'good' DISCERN score and a 'good' VRAI score. The paired *t*-test was used to then assess whether presence of the HON seal was predictive of the specific DISCERN and VRAI scores. A one-way ANOVA test was used to assess whether the website type was significantly related to the specific DISCERN and VRAI scores. Linear regression analysis was used to evaluate the relationship between the DISCERN and VRAI scores as they are both interval variables. A *P* value of less than 0.05 was taken to be statistically significant.

RESULTS

In excess of 891000 websites returned from the Google search. Eighty websites were assessed in total from Google, Yahoo!, and Bing combined. Of the 80 websites, 18 were dedicated to primary hip arthroplasty exclusively, 15 were duplicates and 1 was dedicated to hip hemiarthroplasty for trauma. Forty six websites were analysed once these were excluded (Figure 1).

Of note, there were no allied-health websites, no media-related websites and no social media websites analysed. Academic websites were much more frequent than other website types (39% of total). There were 18 academic websites, 12 physician, 6 commercial, 6 health information, 3 governmental, and 1 unspecified website (Figure 2).

Health on the net

The HON seal was documented in only 6.5% of websites and was significantly associated with certain website types ($P = 0.007$). Governmental websites had the highest number of HON seals with two thirds of governmental websites being HON positive. Health-information websites had 1 HON seal out of a total of 6 websites. There were 18 academic websites reviewed in total and none of these had the HON seal.

DISCERN score

The mean DISCERN score overall was 43/80 ($\sigma = 12.7$; 8-73 range). Twenty-eight percent of websites ($n = 13$) had a 'good' DISCERN score (> 50) whereas only 1 website had an 'excellent' DISCERN score (> 70). This was a governmental website with a score of 73. The lowest DISCERN score was 8/80 recorded for an unspecified website. It was found that websites with the HON seal had significantly higher DISCERN scores ($P = 0.01$). The mean DISCERN score for websites with a HON seal was 54 [$\sigma = 13.8$; 95% confidence interval (CI): 31.9 to 76.0] compared to a mean score of 41.9 for those websites without the HON seal ($\sigma = 12.3$; 95%CI: 38.1 to 45.8).

VRAI score

The mean VRAI score overall was 8.45/20 ($\sigma = 4.5$, 0-17). Twenty-eight percent of websites ($n = 13$) had a 'good' VRAI score. Only one website achieved an 'excellent' score, this was a health information website. Two websites scored 0 including an academic website and a physician website. Health information websites had significantly higher rates of 'good' VRAI scores ($P = 0.008$). Eighty-three percent ($n = 5$) of health information websites had a 'good' VRAI score and one of these was considered 'excellent'. Fifty percent of commercial websites were of 'good' quality ($n = 3$) whereas only 2 of the 18 academic websites had 'good' VRAI scores.

Interobserver variability

Cohen's Kappa coefficient (κ) was calculated for both the DISCERN and the VRAI scores. It was found that the DISCERN scoring system only had a 'fair' level of interobserver agreement ($\kappa = 0.37$). The VRAI score had a much higher rate of interobserver agreement which was classified as 'good' ($\kappa = 0.73$). Simple linear regression analysis was performed to compare the Discern and VRAI scoring systems. There was a statistically significant relationship between the two systems ($P < 0.001$). A scatterplot with a regression reference line was also developed (Figure 3). This illustrates how Discern scores tend to increase with an increasing VRAI score, demonstrating the significant relationship between the two scores.

JAMA benchmark criteria

Twenty-eight percent of websites ($n = 13$) scored 4/4 for the JAMA benchmark criteria. 4 websites scored 0/4. Academic websites had a significantly higher JAMA score compared to other website types ($P < 0.001$). Twelve of the eighteen academic sites scored a JAMA of 4. The remaining websites all scored 3 except for one website that scored a 2. All government, commercial and physician websites failed to score a 4. One health information website scored a 4. Presence of the HON seal was not

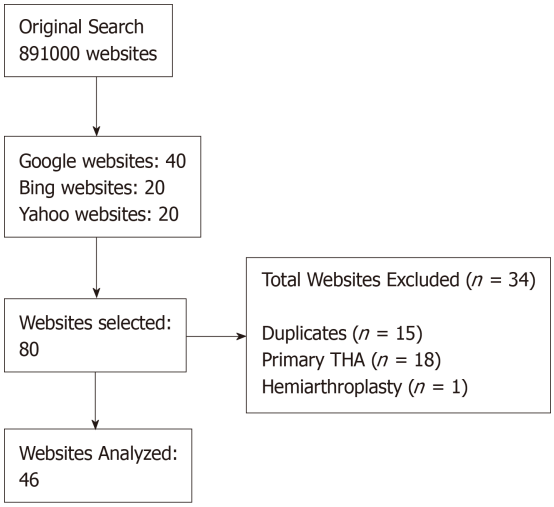

Figure 1 Flow chart on study-selection process.

associated with a higher JAMA score.

Readability

Using the Flesch reading ease model, it was found that the majority of websites were pitched at a reading level above the 8th grade (52%). Four websites had a reading level of the 10th grade. Three websites were written to a college student standard and 36% of all websites (n = 17) were written to a postgraduate standard. The academic websites all had postgraduate reading levels except for one which had a college reading level. Academic websites were found to have a significantly higher reading level than the other websites (P < 0.001). All governmental websites were at a 7th grade level. The majority (10/12) of physician websites were at or below an 8th grade reading level.

DISCUSSION

Revision THA is a procedure that is increasing in demand as time progresses. Kurtz *et al*[3] predicted that between 2005 and 2030, the demand for revision hip arthroplasty procedures would increase by 137%. Between 2009 and 2010 in the United States, the total number of revision THAs increased by 10.8%[15]. With the growing demand for this procedure in the future, the public will naturally become more inquisitive regarding the indications, techniques, recovery times and complications associated with revision hip arthroplasty. It is well known that orthopaedic patients are now frequently utilising online resources to research their own conditions[16]. We anticipate that revision THA will become an increasingly searched entity among patients undergoing this procedure in the future. The quality of internet-based information related to primary THA has been extensively described to date[4,5,17]. The purpose of this study was to analyse the quality of the online resources available to patients undergoing revision THA as this has not been evaluated in the current literature to date.

Surprisingly, of the 46 websites that were analysed in this study, not one of them was a social media website. The use of social media by patients by has been shown to improve the doctor-patient relationship by creating more equal communication[18]. It is perhaps concerning therefore that social media are not a prominent source of information for patients undergoing revision THA. It may be the case however, that the higher age profile of this patient cohort is associated with lower levels of social media participation and this is why there is less reference to revision THA on social media sites.

Academic websites were the commonest website type returned in our search. This is reassuring from a number of perspectives. Academic websites scored the highest consistently on the JAMA benchmark. This means that the source of this information is highly transparent and likely to be current and easily referenced. Unfortunately, the academic websites do have a significantly higher reading level than the other websites that were returned for analysis in the study (P < 0.001). Academic websites also tend to have a very specific aim which may not meet the needs of patients looking for general information on revision THA. All of the academic websites were written at a

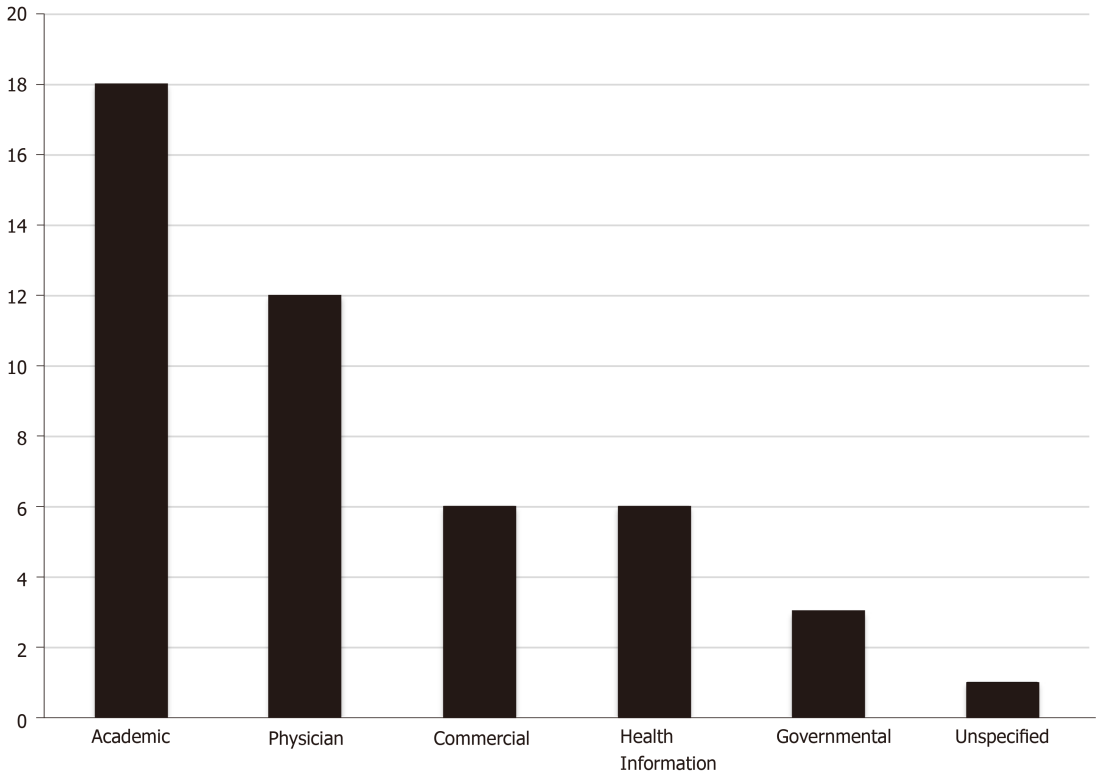

Figure 2 The number of different type of websites.

postgraduate level except for one website which was written at a college level. It has been reported that the average United States resident reads at an 8th grade level and so it is fitting that information intended for public reading should not exceed this level in order to be comprehensible to the vast majority of orthopaedic patients[19]. Considering all academic websites were tailored to a much higher reading level, it can be assumed that these websites are not appropriate sources of information for the vast majority of patients. We found that all governmental sources of information had a 7th grade reading level and so are well suited for relaying information related to revision THR. The majority (10/12) of physician websites also had appropriate reading levels for transmitting information to the public.

The HON seal has been described as a useful tool for physicians to recommend to their patients when searching the internet for information[4]. Previous studies assessing elective orthopaedic information on the internet have found the HON seal present in over 25% of websites[20]. In relation to revision THA information in this study, the HON seal was only found in 6.5% of websites. This demonstrates a much lower standard of quality internet-based information on revision THA when compared to primary THA. Governmental websites had the highest number of HON seals. We found that the HON seal predicts a higher DISCERN score ($P = 0.01$) and is associated with a higher mean DISCERN score, 12 points higher on average than those websites without a HON seal.

Only 28% of websites were classified as 'good' sources of information when using the DISCERN score. When using the novel VRAI score, we also found that only 28% of websites could be classified as 'good' sources of information regarding revision THA. Overall, these figures demonstrate a distinct lack of quality information relating to revision THA on the internet. Cassidy *et al*[21] concluded that the readability and quality of online orthopaedic information is generally poor. We agree with this sentiment as it relates to revision THA and propose that information relating to revision THA is even poorer than information relating to primary THA.

Health information websites appear to be the best sources of information available to patients currently on the internet as they have significantly higher numbers of 'good' VRAI scores ($P = 0.008$). Eighty-three percent of health information websites had 'good' VRAI scores. The only website to score an 'excellent' on the VRAI score was also a health information website. Regression analysis in this study confirms the significant relationship between the validated DISCERN score and the novel VRAI score described ($P < 0.001$). Condition-specific scoring systems are known to be useful

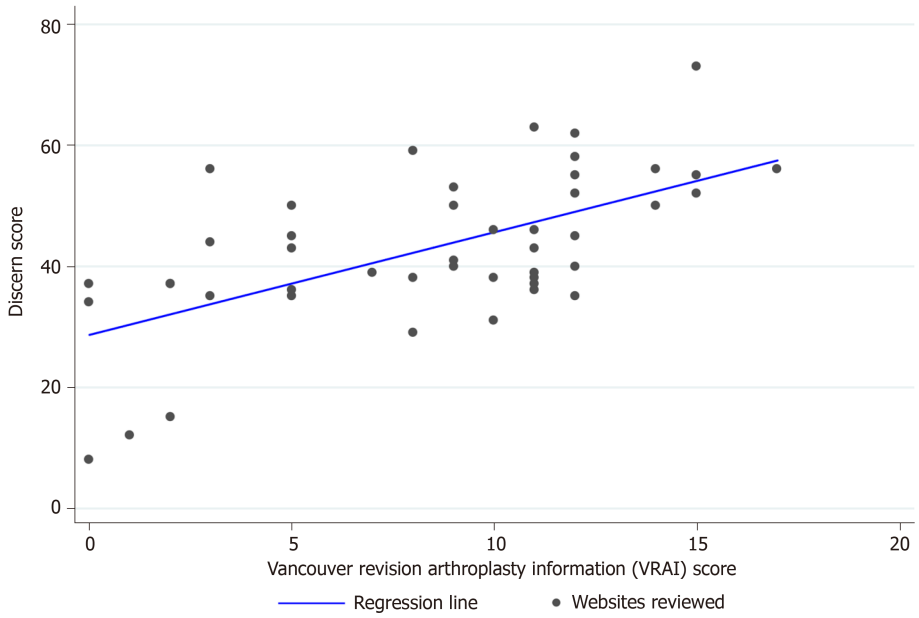

Figure 3 The scatterplot with a regression reference line.

in detailing the type of information that should be included by a source providing information to patients on a specific health-related topic[4]. The 'VRAI' score described here provides a useful template for websites and other information sources to use if comprehensive information is to be given to patients. This score is significantly related to the validated DISCERN score as demonstrated through regression analysis and it also has a much higher interobserver reliability when compared to the DISCERN score as shown in this study.

We also note that the use of a HON seal is associated with better information quality and higher DISCERN scores. Governmental websites have the most appropriate readability levels on the internet in this field whereas academic websites are not deemed suitable for providing information to patients given the niche focus of their content and the very advanced level of readability. Health information websites are the best sources of information for patients undergoing revision THA as determined by the VRAI score.

This study has a number of limitations. The VRAI score operates on a 20-point scale whereas the DISCERN score has 80. Given the discrepancy between the two scales, it may be more difficult for two observers to agree on a DISCERN score compared to a VRAI score. This may account for the higher interobserver reliability seen with the VRAI score compared to the DISCERN score. We propose that the VRAI score is still a very useful tool in delivering quality information relating to revision THA. The threshold for 'good' and 'excellent' VRAI scores were arbitrary. It was thought that these were reasonable values to use however, given the maximum score of 20. Only two authors reviewed the websites that were searched, ideally a higher number of reviewers would improve the accuracy of the analysis. Both reviewers were senior orthopaedic trainees with much experience in the quality assessment of health-related information.

CONCLUSION

Information related to revision THA on the internet is of generally poor quality and seems to be of lower quality than information relating to primary THA on the internet. Only 28% of websites had 'good' quality information as determined by both the validated DISCERN score and the novel revision THA-specific VRAI score. We recommend that patients use governmental websites as these are the most readable on the internet. We also recommend the use of health information websites as these were of the highest quality overall. Academic websites should be avoided as sources of patient information given their advanced readability and overall lack of patient-relevant content relating to revision THA.

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ORIGINAL ARTICLE

Observational Study

Postoperative delirium after major orthopedic surgery

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Author contributions: Urban MK and Magid SK contributed to study conception and design; Sasaki M and Schmucker AM contributed to data acquisition and data analysis; Urban MK and Sasaki M contributed to the interpretation and writing of the article; Urban MK, Sasaki M, Schmucker AM and Magid SK contributed to editing, reviewing and final approval of the article.

Institutional review board statement: All human subject research conducted during the course of this study was approved by the Hospital for Special Surgery Institutional Review Board.

Informed consent statement: This study could not practicably be carried out without the waiver of HIPAA authorization since patients were not scheduled to return for follow-up. A waiver of documentation of informed consent according to 45 CFR 46.117(c) and a waiver of HIPAA authorization in accordance with 45 CRF 164.512(i) was obtained prior to the start of study activities.

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Abstract

BACKGROUND

Postoperative delirium (POD) is one of the most common complications in older adult patients undergoing elective surgery. Few studies have compared, within the same institution, the type of surgery, risk factors and type of anesthesia and analgesia associated with the development of POD.

AIM

To investigate the following three questions: (1) What is the incidence of POD after non-ambulatory orthopedic surgery at a high-volume orthopedic specialty hospital? (2) Does surgical procedure influence incidence of POD after non-ambulatory orthopedic surgery? And (3) For POD after non-ambulatory orthopedic surgery, what are modifiable risk factors?

METHODS

A retrospective cohort study was conducted of all non-ambulatory orthopedic surgeries at a single orthopedic specialty hospital between 2009 and 2014. Patients under 18 years were excluded from the cohort. Patient characteristics and medical history were obtained from electronic medical records. Patients with POD were identified using International Classification of Diseases, 9th Revision (ICD-9) codes that were not present on admission. For incidence analyses, the cohort was grouped into total hip arthroplasty (THA), bilateral THA, total knee arthroplasty (TKA), bilateral TKA, spine fusion, other spine procedures, femur/pelvic fracture, and other procedures using ICD-9 codes. For descriptive

additional data are available.

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and regression analyses, the cohort was grouped, using ICD-9 codes, into THA, TKA, spinal fusions, and all procedures.

RESULTS

Of 78492 surgical inpatient surgeries, the incidence from 2009 to 2014 was 1.2% with 959 diagnosed with POD. The incidence of POD was higher in patients undergoing spinal fusions (3.3%) than for patients undergoing THA (0.8%); THA patients had the lowest incidence. Also, urgent and/or emergent procedures, defined by femoral and pelvic fractures, had the highest incidence of POD (7.2%) than all other procedures. General anesthesia was not seen as a significant risk factor for POD for any procedure type; however, IV patient-controlled analgesia was a significant risk factor for patients undergoing THA [Odds ratio (OR) = 1.98, 95% confidence interval (CI): 1.19 to 3.28, $P = 0.008$]. Significant risk factors for POD included advanced age (for THA, OR = 4.9, 95%CI: 3.0-7.9, $P < 0.001$; for TKA, OR = 2.16, 95%CI: 1.58-2.94, $P < 0.001$), American Society of Anesthesiologists score of 3 or higher (for THA, OR = 2.01, 95%CI: 1.33-3.05, $P < 0.001$), multiple medical comorbidities, hyponatremia (for THA, OR = 2.36, 95%CI: 1.54 to 3.64, $P < 0.001$), parenteral diazepam (for THA, OR = 5.05, 95%CI: 1.5-16.97, $P = 0.009$; for TKA, OR = 4.40, 95%CI: 1.52-12.75, $P = 0.007$; for spine fusion, OR = 2.17, 95%CI: 1.19-3.97, $P = 0.01$), chronic opioid dependence (for THA, OR = 7.11, 95%CI: 3.26-15.51, $P < 0.001$; for TKA, OR = 2.98, 95%CI: 1.38-6.41, $P = 0.005$) and alcohol dependence (for THA, OR = 5.05, 95%CI: 2.72-9.37, $P < 0.001$; for TKA, OR = 6.40, 95%CI: 4.00-10.26, $P < 0.001$; for spine fusion, OR = 6.64, 95%CI: 3.72-11.85, $P < 0.001$).

CONCLUSION

POD is lower (1.2%) than previously reported; likely due to the use of multi-modal regional anesthesia and early ambulation. Both fixed and modifiable factors are identified.

Key words: Delirium; Arthroplasty; Replacement; Knee; Hip; Risk factors; Pain management; Spinal fusion; Orthopedics; Incidence; Anesthesia; General; Opioid-related disorders; Narcotics

Core tip: This original research adds significantly to the perioperative literature. At this single orthopedic institution, the effects of different procedures, and effects of the different management practices of these procedures, on postoperative delirium were examined. The incidence of post-operative delirium was found to be lower at this institution than many other previous reports. Potentially modifiable risk factors for post-operative delirium in patients undergoing common orthopedic procedures, for whom higher vigilance is warranted were also identified.

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INTRODUCTION

Postoperative delirium (POD) is one of the most common complications in older adult patients undergoing elective surgery. The reported incidence ranges from 3%-25% after elective surgery[1,2]. Many perioperative characteristics have been associated with the development of POD including increased length of recovery and hospital stay, as well as increased morbidity and mortality[1,3]. Fixed risk factors often associated with POD include advanced age, pre-existing central nervous system deficits, psychiatric disease, alcohol abuse, emergency surgery and the presence of multiple comorbidities[3,4]. Few studies have compared, within the same institution, the type of surgery, risk factors and type of anesthesia and analgesia associated with the

development of POD[5]. Our goal was to assess the incidence of POD after non-ambulatory orthopedic surgery, evaluate the influence of the surgical procedure on this incidence, and identify possible modifiable risk factors.

MATERIALS AND METHODS

Study population and data collection

With the approval of the Institutional Review Board a retrospective cohort study was conducted of all non-ambulatory orthopedic surgeries at a single orthopedic specialty hospital between 2009 and 2014. Specifically, the study population was patients aged 18 years or older who underwent inpatient orthopedic surgeries from January 1, 2009 to December 31, 2014 at a single institution. Excluded populations were patients aged 17 years or younger and patients who did not undergo an inpatient orthopedic surgery. These patient populations were excluded to minimize selection bias as younger patients are less likely to develop delirium and ambulatory patients are not routinely followed to see if there is an occurrence of delirium after surgery.

The initial study design included years prior to 2009; but it was determined that differences in coding before 2009 would affect the interpretation of the data and contribute to disease misclassification bias, so data prior to 2009 was excluded. Patient characteristics and medical history were obtained from electronic medical records. Patient's medical diagnoses, including Elixhauser comorbidity score determination[6] and procedure types were obtained from International Classification of Diseases, 9th Revision (ICD-9) codes. Age, sex, BMI, postoperative medications, laboratory values, American Society of Anesthesiologists' (ASA) score, and whether a computerized axial tomography (CT) scan or magnetic resonance imaging (MRI) scan of the brain was ordered were obtained from the electronic health record (Allscripts, Atlanta, Georgia).

Procedure grouping

For incidence analyses, the cohort was grouped into total hip arthroplasty (THA), bilateral THA, total knee arthroplasty (TKA), bilateral TKA, spine fusion, other spine procedures, femur/pelvic fracture and other procedures using ICD-9 procedure codes. For descriptive and regression analysis, the cohort was grouped, using ICD-9 procedure codes, into THA, TKA, spinal fusions, and all procedures. Emergent procedures were excluded in the descriptive and regression analyses to minimize selection bias as the characteristics of patients undergoing emergent surgeries and the characteristics of these surgeries themselves may be related to the development of delirium. Patients in the THA and TKA group were identified by 81.51 and 81.54 ICD-9 codes, respectively. Bilateral THA and bilateral TKA patients were identified by the presence of 81.51 coded twice or 81.54 coded twice during one admission stay, respectively. Spinal fusion patients were identified using one or more of the following codes: 81.03, 81.05, 81.07, 81.08, 81.33, 81.33, 81.35, 81.37, 81.38, 81.62, 81.63, 81.64 and 84.51, representing anterior, posterior, or revision spine fusions. Other spine patients were identified by a presence of one or more of 3.0-3.99, 81.00-81.08, 81.30-81.39, 84.60-84.69 and 84.80-84.85 codes. Femur and/or pelvic fracture patients were identified by one or more of the following codes: 808.0-808.9, 820.0-820.9 and 821.0-821.3 ICD-9 codes. Patients in the other-procedure grouping were inpatients who underwent orthopedic surgery without the presence of any of the codes listed above during the duration of the study. The all-procedure grouping consisted of all adult inpatient orthopedic surgeries that occurred during the study period, which encompasses all the groups listed above. To examine non-emergent surgeries, the THA, TKA and spinal fusion groupings excluded patients if they had the following present on admission: Cardiovascular accident, deep vein thrombosis, pulmonary embolism, acute myocardial infarction, acute kidney failure, hip fracture, pneumonia, respiratory failure, sepsis and trauma. The all-procedure grouping included emergent procedures. The THA grouping only included patients with an ASA score of 2 and above. Since no THA patients with an ASA score of 1 had POD, the regression analysis was restricted to patients with ASA score of 2 and above to allow for THA patients with ASA score 2 to serve as the reference group in the regression model. This was preferred over grouping patients with ASA score 1 and 2 into one group to serve as the reference since this would bias the results as there would be no THA POD patients with an ASA score of 1 in this group.

POD identification

Patients with POD were identified using the following ICD-9 codes, provided that these conditions were not present on admission: 290.11; 290.3; 291.0; 292.81; 293.0;

293.1; 293.9; 300.11; 300.14; 300.15; 348.31; and 780.09 (Figure 1). There were no patients with ICD-9 codes 290.11 and 300.14 and only a total of 4 with ICD-9 codes 293.1, 300.11 and 300.15. All patients in the post-operative care unit, step down unit and intensive care unit (ICU) were assessed for delirium using the confusion assessment method for the ICU (CAM-ICU) scale. Once transferred to a non-monitored bed in the hospital, during each nursing shift, the covering nurse conducted a CAM-ICU assessment on their assigned patients. If the nurses detected a change in mental status, a physician assistant or nurse practitioner was requested to confirm the diagnosis and report the change to a covering physician. The diagnosis of delirium and/or change in mental status was only made after a practitioner entered the diagnosis in the patient's medical record. Opioid dependence was identified using any ICD-9 diagnosis code, if present on admission, between 304.00 and 304.93, as well as code V58.69. The occurrence of a postoperative thiamine order was used as a proxy for alcohol abuse. Pressure ulcers were identified by the following ICD-9 diagnosis codes if present on admission: 707.01, 707.02, 707.03, 707.04, 707.05, 707.06, 707.07, 707.09, 707.23 and 707.24. atrial fibrillation (Afib) was identified by the 427.31 ICD-9 diagnosis code if present on admission. Preoperative hyponatremia was defined by a sodium value < 135 mmol/L within 30 days before admission.

Statistical analysis

Preliminary descriptive statistical analysis consisted of frequency counts and percentages for discrete variables and median, intra-quartile range, and minimum and maximum values for continuous variables. Crude inferential analysis consisted of Chi-square and Fisher Exact tests for discrete comparisons and independent samples *t*-tests for continuous variables. When continuous variables failed to meet the assumption of normality using the Kolmogorov-Smirnov test, non-parametric Mann Whitney U tests were used in place of *t*-tests. Multivariable logistic regression analysis was used to identify potential risk factors POD while adjusting for any potential confounding. Records with missing data for the regression variable candidates were removed from the analyses. Patients with more than one admission in the study had each admission treated separately. Separate models for spinal fusion, hip arthroplasty, and knee arthroplasty were constructed and separate models with Elixhauser comorbidities and Charlson Comorbidity scores[7,8] were constructed for each procedure type. The models with the Charlson Comorbidity scores were used for sensitivity analyses. Based on age categorizations in the literature, age was treated as a binary variable for all procedure type models; arthroplasty models had patients 70 years old or older *vs* patients less than 70 years old and spine models had patients 65 years old or older *vs* patients less than 65 years old[4,9-11]. Multicollinearity for each model was checked and no covariates had a variance inflation factor above 2.0, so they were considered not to be collinear. A model was constructed including, *a priori*, all patient and clinical variables that were thought to be risk factors, based on literature and physician expertise. Significance was set at 0.05 for all analyses without multiple comparison adjustment since the study was evaluating a single hypothesis: Predictors of delirium. All analyses were performed using SAS 9.3 (Cary, NC, United States). The statistical methods of this study were reviewed by Kara Fields and Joseph T Nguyen from Hospital for Special Surgery.

RESULTS

The incidence of POD was assessed in patients 18 years old or older undergoing non-ambulatory surgery at an orthopedic institution from 2009 to 2014. During this time, there were 78492 surgical inpatient surgeries. Of these patients; 959 were diagnosed with POD; an incidence of 1.2%. The most common diagnostic categories of delirium included altered consciousness, drug induced delirium, and metabolic encephalopathy. The reported incidence of POD increased from 2009 to 2012, and then plateaued from 2012 to 2014 (Figure 2); the majority of the increase occurred in the diagnostic ICD-9 code 293.0 for "delirium due to conditions classified elsewhere."

The incidence of delirium varied between the orthopedic surgical procedures (Table 1). The incidence of POD was higher in patients undergoing spinal fusions than for patients undergoing THA, THA patients had the lowest incidence. Also, urgent and/or emergent procedures defined by femoral and pelvic fractures had the highest incidence of POD than all other procedures (Table 1). Of the 78492 inpatient surgeries, 35166 patients were males (44.8%) and 43326 were females (55.2%). The mean age was 62 years (SD ± 14). The mean BMI was 28.8 (SD ± 6.1). Table 2 contains the patient characteristics for all patients undergoing a major elective orthopedic surgery. For these patients, there was a statistically significant difference in age between POD and

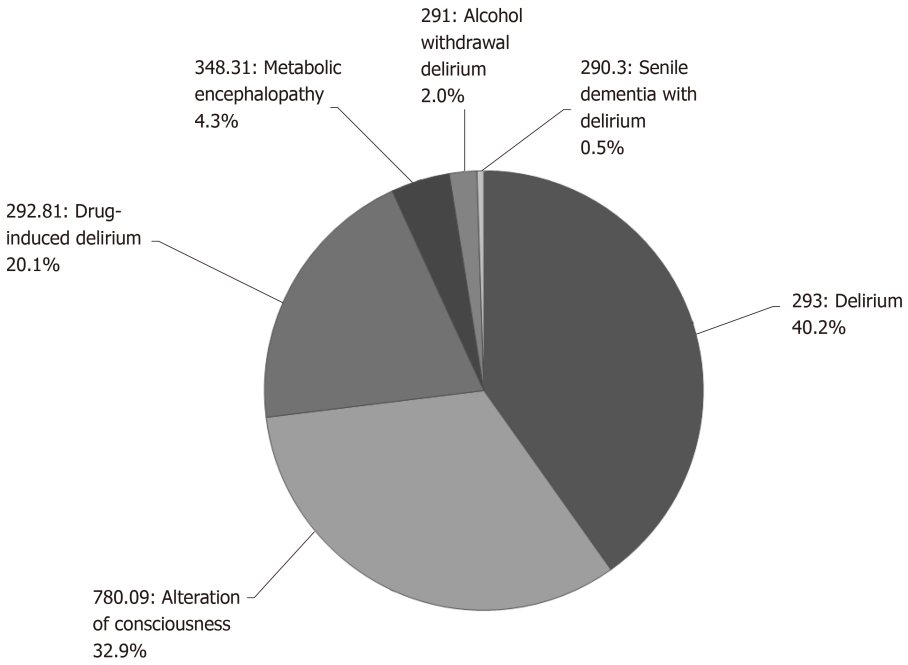

Figure 1 The chart shows International Classification of Diseases, Ninth Revision, Clinical Modification codes used for the diagnosis of postoperative delirium.

non-POD patients, with an incidence of 2.5% in patients 70 years old or older compared to an incidence of 0.006% in patients under 70 years old. Patients with POD had higher ASA scores, where 45.7% of POD patients had an ASA score of 3 or higher with an incidence of 3.0% compared to a POD incidence of 0.008% for patients with an ASA score of 2 or lower. Additionally, POD was significantly higher in patients receiving postoperative benzodiazepines; 10.2% of the patients with POD received diazepam *vs* only 4.0% of the non-POD population. Significantly more narcotics were used by patients with POD than those without. Perioperative thiamine administration which is a marker for pre-existing alcohol use was more common in POD patients. Also, Afib on admission was more common in patients who developed POD than in non-POD patients. Tables 3 and 4 show the patient characteristics of THA and TKA patients. POD was more common in patients 70 years or older in patients undergoing THA and TKA procedures; 80.0% of THA and 69.8% of TKA patients with POD were 70 years old or older *vs* 35.7% of THA and 41.8% of TKA patients without POD. For TKA patients, the incidence of patients who received a general anesthetic (GA) was 4.9% in POD patients; however only 2.7% of the non-POD TKA patients received a GA for surgery. This statistically significant difference was also seen with the type of postoperative analgesia. The incidence of POD among patients who received epidural patient-controlled analgesia (PCA) was 0.7% for THA patients and 1.2% for TKA patients. In comparison, the incidence of POD among THA patients who received intravenous PCA was 1.2% for THA and 2.1% for TKA patients. In our analysis, 90.7% of the THA patients with a diagnosis of POD had either a CT, MRI or both.

Table 5 presents the data for spine fusion patients, with similar findings that patients with POD are older with a history of psychiatric illness, opioid dependence, alcohol use and have more comorbidities.

Using regression analysis we identified perioperative risk factors with a significant association with POD, for patients undergoing a THA, TKA or spinal fusion, while controlling for age, sex, BMI, creatinine levels, hyponatremia, thiamine order (alcohol abuse), ASA status, Afib, opioid dependence, pressure ulcers (for THA and spine fusion models only), PCA route, anesthesia type, surgery length, administration of parenteral diazepam, and Elixhauser comorbidities (Table 6). Three additional models were built with the same covariates but with Charslon Comorbidity scores in place of the Elixhauser comorbidities for sensitivity analyses. 42725 of 78492 surgical inpatient surgeries were eligible for regression analyses as only non-emergent THA, TKA and spine fusion patients were included in the regression analyses. Records with missing data for candidate variables were also removed from analyses resulting in 18276 of 18372 eligible patients in the THA model, with 140 of 140 eligible cases remaining; 19987 of 20109 eligible patients in the TKA model, with 245 of 245 eligible cases

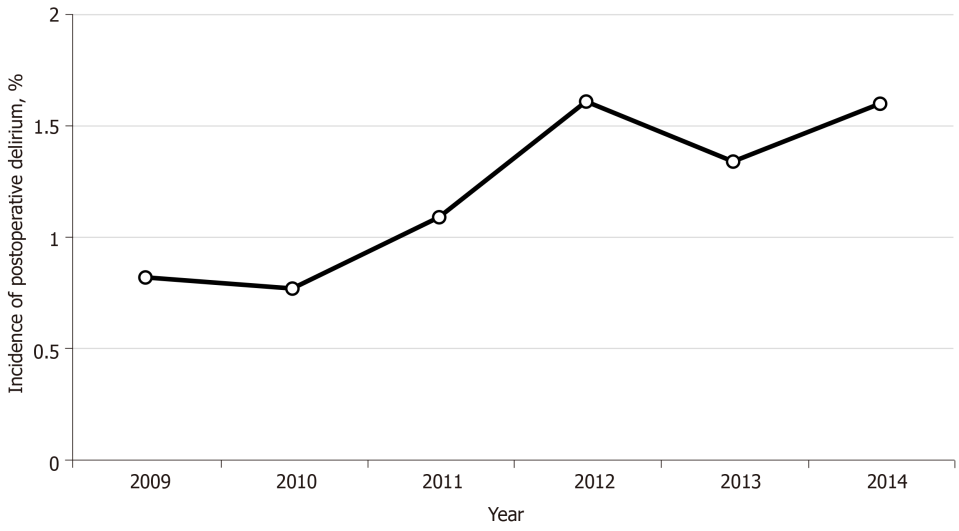

Figure 2 The graph shows the incidence of postoperative delirium by year from 2009 to 2014.

remaining; and 4183 of 4244 eligible patients in the spine fusion model, with 136 of 137 cases remaining.

Older age remained a significant risk factor for POD for THA, TKA and spine fusion patients. GA was not seen as a significant risk factor for POD for any procedure type. However, IV PCA remained a significant risk factor for patients undergoing a THA. ASA score of 3 or higher and preoperative hyponatremia remained significant risk factors for THA patients only. Finally, parenteral diazepam, chronic opioid dependence and postoperative thiamine order were significant risk factors for POD for THA, TKA, and spine fusion patients. Models with the Charlson Comorbidity scores provided similar results as with models that included the Elixhauser comorbidities.

DISCUSSION

Over a 6-year period in a cohort of 78492 adult patients undergoing non-ambulatory orthopedic surgery, the incidence of POD was 1.2%. Many of the risk factors identified have been cited in previous reports and are not amenable to modification: Advanced age, medical comorbidities, and a history of psychiatric disease. However, some risk factors such as pre-existing narcotic dependence, alcoholism, and hyponatremia are potentially modifiable. In addition to surgical procedure, type of anesthesia and type of postoperative analgesia may affect the incidence of POD and as such be targeted in an attempt to reduce the incidence of POD.

This study had some limitations. First, this study provided insight into the incidence of POD at a single orthopedic specialty institution where the contribution of different procedures and anesthetic/analgesic approaches to the development of POD could be assessed. Since we relied on the reporting of mental status changes using the CAM-ICU methodology, patients with subtle changes in cognition or hypoactive delirium may have been omitted in our tabulation biasing the results toward the null, although the magnitude of this bias would be small. Second, older patients with unrecognized dementia and confusion on admission may have been incorrectly diagnosed with new acute POD biasing the results away from the null, the magnitude of this bias would also be small. A modifiable approach to reduce the incidence of POD has been to target and decrease the use of preoperative polypharmacy involving psychotropic medications[12,13]. This report did not track preoperative medications thus allowing for possible confounding where preoperative psychotropic medications may account for some of the POD incidence seen in this population. Third, we, as others[14], noted an association between preoperative alcohol use and POD. In this report, however we use postoperative administration of thiamine as an indicator of increased preoperative alcohol consumption. Although, it is our policy to administer thiamine to all patients believed to be at risk for alcohol withdrawal, it is possible that some patients may have been omitted biasing the results toward the null, the magnitude of this bias would be small.

The incidence of POD reported in this study is lower than what has been reported

Table 1 Incidence for postoperative delirium in specific orthopedic procedures from 2009 to 2014

Procedure	Incidence (%)
Primary THA	0.8
Bilateral THA	0.4
Primary TKA	1.2
Bilateral TKA	1.2
Spine fusion	3.3
Other spine procedures	1.9
Femur/pelvic fracture	7.2
Other procedures	1.0

THA: Total hip arthroplasty; TKA: Total knee arthroplasty.

in many previous studies[1,15]. Even in patients greater than 70 years old, our reported incidence of 2.5% is considerably below the reported rates of 15%-20% after elective surgery[12] and 50% after the repair of hip fractures[16]. However, there are reports of a lower incidence of POD in at-risk patient populations[5,17]; Chung *et al*[18], reported a POD incidence of 3.1% after TKA. Several studies have suggested that the hospital incidence of delirium is under-reported due to the methods used to identify patients with delirium, which often miss patients with hypoactive delirium[19,20]. In the present report, the CAM-ICU algorithm was utilized by nurses to identify patients with a change in mental status. The diagnosis of delirium using CAM-ICU features has been shown to have improved sensitivity compared to observational assessment alone[21]. In addition, in this study the diagnosis was confirmed by a practitioner before the diagnosis was entered into the medical record. Furthermore, early ambulation and multi-modal analgesia which in multiple studies has been shown to reduce the incidence of POD, is a major factor in the postoperative management of the patients in this report. Thus, we believe the incidence of POD reported in this study is accurately represented.

The incidence of delirium varied between the various non-ambulatory surgical procedures. Pelvic and hip fractures demonstrated the highest rate followed by spinal fusions and then knee arthroplasty. Patients undergoing TKA are older, generally have more pain, increased comorbidities, lose more blood with subsequent increased intravenous fluid infusions, and are hospitalized longer at our institution than those undergoing THA[22]. All of these factors could have contributed to an increase in POD. Weinstein *et al*[5] also reported an increased incidence of POD in TKA patients compared to THA patients. Although the spinal fusion patients were younger; these patients all were subjected to GA including 97% who also received intravenous PCA narcotics for analgesia. Fineberg *et al*[9] also reported a higher incidence of POD among spinal fusion patients. We did not find arthroplasty patients undergoing GA had a higher risk of POD than patients who received a regional anesthetic. However, this difference was present in the type of postoperative analgesia received for THA patients; epidural PCA *vs* intravenous PCA. Some studies have suggested an association between GA and the development of delirium[5]. However, conflicting reports have been published questioning the role of GA in POD[23,24]. Weinstein *et al*[5] using a similar data base at our institution, found similarly low rates of POD for arthroplasty patients with a higher reported incidence in those patients receiving GA. However, at this institution over 97% of the primary arthroplasty patients received a neuraxial anesthetic for surgery with most cases having GA reserved for patients with contraindications to a spinal or epidural anesthetic (*e.g.*, coagulopathy or previous spinal fusion). Hence, this finding may be confounded by uncontrolled factors. Furthermore, the degree of sedation delivered for the regional anesthetic patients was not recorded or controlled for in this study. Sieber *et al*[25] reported that in those patients who received spinal anesthesia with deep sedation *vs* "light" sedation for the repair of hip fractures, the incidence of POD was twice as high. However, this dramatic reduction in POD with reduced sedation was not confirmed in the STRIDE study, where the authors suggested that the benefits of reduced sedation may be obscured by competing baseline comorbidities[26].

We found that preoperative narcotic dependence was a major risk factor for the development of POD for THA, TKA and spine fusion patients. Opioid-tolerant patients require higher doses of postoperative opioids, and their pain is more difficult to control. The administration of postoperative opioids, particularly intravenous PCA,

Table 2 Patient demographics and study population

	POD (Mean +/- SD or *n*, %), *n* = 959	Non-POD (Mean +/- SD or *n*, %), *n* = 77533	*P* value
Age, yr	72.7+/-12.9	62.3+/-14.1	< 0.001[a]
≥ 70	610 (63.6)	24038 (31.0)	< 0.001[a]
Male	389 (40.6)	34777 (44.9)	0.008[a]
BMI	28.2+/-6.2	28.0+/-6.1	0.003[a]
Procedure type			< 0.001[a]
THA	161 (16.8)	19753 (25.5)	
TKA	249 (26.0)	20106 (25.9)	
Bilateral THA	3 (0.3)	853 (1.1)	
Bilateral TKA	29 (3.0)	2337 (3.0)	
Spine fusions	140 (14.6)	4135 (5.3)	
Other spine procedures	126 (13.1)	6587 (8.5)	
Other procedures	251 (26.2)	23762 (30.7)	
Trauma			< 0.001[a]
Fracture of femur/pelvis	57 (5.9)	731 (0.9)	
Other trauma	30 (3.1)	2607 (3.4)	
No trauma	872 (90.9)	74195 (95.7)	
Length of stay	6.0+/-7.5	3.0+/-3.2	< 0.001[a]
Latest creatinine before surgery			< 0.001[a]
< 1.2 mg/dL	825 (86.0)	71048 (91.6)	
1.2-2.0 mg/dL	123 (12.8)	6229 (8.0)	
> 2.0 mg/d	11 (1.2)	256 (0.3)	
Preoperative hyponatremia			< 0.001[a]
Yes	367 (38.3)	21290 (27.5)	
No	591 (61.6)	56190 (72.5)	
Missing	1 (0.1)	53 (0.07)	
Postoperative thiamine order			< 0.001[a]
Yes	119 (12.4)	1390 (1.8)	
No	839 (87.5)	76122 (98.2)	
Missing	1 (0.1)	21 (0.03)	
Atrial fibrillation (present on admission)	130 (13.6)	3815 (4.9)	< 0.001[a]
Pressure ulcers (present on admission)	23 (2.4)	323 (0.42)	< 0.001[a]
Opioid dependence or long-term use	29 (6.2)	1245 (1.6)	< 0.001[a]
Psychiatric disease (present on admission)	356 (37.1)	16716 (21.6)	< 0.001[a]
Anesthesia type			< 0.001[a]
General	344 (35.9)	16356 (21.9)	
Other	578 (60.3)	56067 (72.3)	
Missing	37 (3.9)	4510 (5.8)	
Patient-controlled analgesia			< 0.001[a]
Epidural	413 (43.1)	40991 (52.9)	
IV	441 (46.0)	22458 (29.0)	
Peripheral nerve infusion	11 (1.2)	949 (1.2)	
Missing	94 (9.8)	13135 (16.9)	
Received diazepam			< 0.001[a]
Yes	98 (10.2)	3135 (4.0)	
No	860 (89.7)	74377 (95.9)	
Missing	1 (0.1)	21 (0.03)	
CT, MRI or both performed			< 0.001[a]
Yes	872 (90.9)	64838 (83.6)	
No	86 (9.0)	12674 (16.4)	
Missing	1 (0.1)	21 (0.03)	
ASA score			< 0.001[a]
1	7 (0.73)	4933 (6.4)	

2	477 (49.7)	53801 (69.4)
≥ 3	438 (45.7)	14274 (18.4)
Missing	37 (3.9)	4525 (5.8)

[a]$P < 0.05$. POD: Postoperative delirium; THA: Total hip arthroplasty; TKA: Total knee arthroplasty; ASA: American society of anesthesiologists; BMI: Body mass index; SD: Standard deviation; CT: Computed tomography; MRI: Magnetic resonance imaging.

has been associated with sleep disturbances, cognitive impairment, and delirium[11,15]. Some studies have also suggested an association between ketamine administration and postoperative confusion[5]. However, perioperative administration of ketamine is often used to manage chronic pain in patients and reduce narcotic requirements[27]. Hence, a direct association between ketamine and delirium is inconclusive[28]. In this study and others[12,19], the postoperative administration of diazepam was associated with the development of POD. Diazepam is not utilized at this institution to treat postoperative confusion, but is instead used to treat anxiety or to prevent benzodiazepine withdrawal.

In summary, we found, in an orthopedic surgical population, an association between POD and many of the unmodifiable risk factors which have been identified in previous reports, including older age, history of psychiatric disease and multiple medical comorbidities. The incidence of POD was lower than many other previous reports, possibly due to our reliance on regional anesthesia and analgesia for many procedures, a commitment to early ambulation for all of our patients and the pursuit of narcotic-avoidance postoperative analgesia. Entering surgery as an opioid tolerant patient significantly increases the risk of POD and all efforts should be aimed at reducing the preoperative narcotic requirements of these patients and a postoperative analgesic protocol which emphasizes a non-narcotic approach should be used. For those patients at risk for POD a multifactorial intervention approach which includes multi-modal analgesia which de-emphasizes opioids, a reduction in the administration of psycho-active medications, preoperative alcohol use counselling and abstinence, early postoperative ambulation and possible early intervention with dexmedetomidate or atypical anti-psychotic medications is recommended for patients undergoing elective orthopedic inpatient surgery.

Table 3 Total hip arthroplasty patient demographics and study population[1]

	POD (Mean +/- SD or *n*, %), *n* = 140	Non-POD (Mean +/- SD or *n*, %), *n* = 18232	*P* value
Age, yr	77.6+/-10.4	65.5+/-11.4	< 0.001[a]
≥ 70	112 (80.0)	6499 (35.65)	< 0.001[a]
Male	57 (40.7)	7891 (43.28)	0.54
BMI	26.7+/-5.2	28.4+/-5.8	< 0.001[a]
Length of stay	6.1+/-4.0	3.3+/-1.5	< 0.001[a]
Latest creatinine before surgery			< 0.001[a]
< 1.2 mg/dL	107 (76.4)	16376 (89.8)	
1.2-2.0 mg/dL	29 (20.7)	1781 (9.8)	
> 2.0 mg/dL	4 (2.9)	75 (0.4)	
Preoperative hyponatremia			< 0.001[a]
Yes	40 (28.6)	2525 (13.9)	
No	100 (71.4)	15700 (86.1)	
Missing	0 (0)	7 (0.04)	
Postoperative thiamine order			< 0.001[a]
Yes	17 (12.1)	387 (2.1)	
No	123 (87.9)	17844 (97.9)	
Missing	0 (0)	1 (0.01)	
Atrial fibrillation (present on admission)	5 (3.6)	119 (0.7)	< 0.001[a]
Pressure ulcers (present on admission)	1 (0.7)	47 (0.3)	0.31
Opioid dependence or long-term use	9 (6.4)	199 (1.1)	< 0.001[a]
Psychiatric disease (present on admission)	47 (33.6)	3584 (19.7)	< 0.001[a]
Anesthesia type			0.55
General	4 (2.7)	384 (2.1)	
Other	136 (97.1)	17805 (97.7)	
Missing	0 (0)	40 (0.2)	
Patient-controlled analgesia			< 0.001[a]
Epidural	102 (72.9)	14235 (78.1)	
IV	24 (17.1)	1306 (7.2)	
Missing	14 (10)	2691 (14.8)	
Received diazepam			0.03[a]
Yes	8 (5.7)	453 (2.5)	
No	132 (94.3)	17778 (97.5)	
Missing	0 (0)	1 (0.01)	
CT, MRI or both performed			0.009[a]
Yes	127 (90.7)	15616 (85.7)	
No	13 (9.3)	2615 (14.3)	
Missing	0 (0)	1 (0.01)	
ASA score			< 0.001[a]
2	73 (52.1)	14667 (80.5)	
≥ 3	67 (47.9)	3519 (19.3)	
Missing	0 (0)	46 (0.25)	

[1]Only includes total hip arthroplasty patients with American society of anesthesiologists score of 2 or higher.
[a]*P* value < 0.05. POD: Postoperative delirium; ASA: American society of anesthesiologists; CT: Computed tomography; MRI: Magnetic resonance imaging; BMI: Body mass index; SD: Standard deviation.

Table 4 Total knee arthroplasty patient demographics and study population

	POD (Mean +/- SD or *n*, %), *n* = 245	non-POD (Mean +/- SD or *n*, %), *n* = 19864	*P* value
Age, yr	75.1+/-9.3	67.6+/-10	< 0.001[a]
≥ 70	171 (69.8)	8304 (41.8)	< 0.001[a]
Male	89 (36.3)	7364 (37.1)	0.81

BMI	30.0+/-6.1	30.6+/-6.3	0.13
Length of stay	6.0+/-3.2	3.8+/-1.5	< 0.001[a]
Latest creatinine before surgery			< 0.001[a]
< 1.2 mg/dL	203 (82.9)	17828 (89.8)	
1.2-2.0 mg/dL	37 (15.1)	1954 (9.8)	
> 2.0 mg/dL	5 (2.0)	82 (0.4)	
Preoperative hyponatremia			0.07
Yes	45 (18.4)	2837 (14.3)	
No	200 (81.6)	17019 (85.7)	
Missing	0 (0)	8 (0.04)	
Postoperative thiamine order			< 0.001[a]
Yes	28 (11.4)	332 (1.7)	
No	217 (88.6)	19530 (98.3)	
Missing	0 (0)	2 (0.01)	
Atrial fibrillation (present on admission)	46 (18.8)	1190 (6.0)	< 0.001[a]
Pressure ulcers (present on admission)	1 (0.4)	29 (0.2)	0.31
Opioid dependence or long-term use	9 (3.7)	198 (1.0)	0.001[a]
Psychiatric disease (present on admission)	77 (31.4)	3915 (19.7)	< 0.001[a]
Anesthesia type			0.04[a]
General	12 (4.9)	545 (2.7)	
Other	233 (95.1)	19252 (96.9)	
Missing	0 (0)	67 (0.3)	
Patient-controlled analgesia			0.005[a]
Epidural	179 (73.1)	15151 (76.3)	
IV	38 (15.5)	1801 (9.1)	
Peripheral nerve infusion	9 (3.7)	711 (3.6)	
Missing	19 (7.8)	2201 (11.1)	
Received diazepam			0.003[a]
Yes	12 (4.9)	381 (1.9)	
No	233 (95.1)	19481 (98.1)	
Missing	0 (0)	2 (0.01)	
CT, MRI or both performed			0.14
Yes	226 (92.2)	17733 (89.3)	
No	19 (7.8)	2129 (10.7)	
Missing	0 (0)	2 (0.01)	
ASA score			< 0.001[a]
1	2 (0.8)	489 (2.46)	
2	130 (53.1)	14933 (75.2)	
≥ 3	113 (46.1)	4327 (22.0)	
Missing	0 (0)	70 (0.4)	

[a]*P* value < 0.05. POD: Postoperative delirium; ASA: American society of anesthesiologists; CT: Computed tomography; MRI: Magnetic resonance imaging; BMI: Body mass index; SD: Standard deviation.

Table 5 Spine fusion patient demographics and study population

	POD (Mean +/- SD or *n*, %), *n* = 137	non-POD (Mean +/- SD or *n*, %), *n* = 4107	*P* value
Age, yr	67.5+/-12.5	60.1+/-15.6	< 0.001[a]
≥ 65	91 (66.4)	1765 (43.0)	< 0.001[a]
Male	54 (39.4)	1810 (44.1)	0.28
BMI	28.5+/-6.5	28.1+/-5.9	0.40
Length of stay	9.0+/-5.1	5.6+/-3.6	< 0.001[a]
Latest creatinine before surgery			0.01[a]
< 1.2 mg/dL	116 (84.7)	3754 (91.4)	
1.2-2.0 mg/dL	20 (14.6)	346 (8.4)	

> 2.0 mg/dL	1 (0.7)	7 (0.2)	
Preoperative hyponatremia			0.16
Yes	43 (31.4)	1070 (26.1)	
No	94 (68.6)	3033 (73.9)	
Missing	0 (0)	4 (0.1)	
Postoperative thiamine order			< 0.001[a]
Yes	20 (14.6)	93 (2.3)	
No	117 (85.4)	4013 (97.7)	
Missing	0 (0)	1 (0.02)	
Atrial fibrillation (present on admission)	12 (8.8)	135 (3.3)	0.003[a]
Pressure ulcers (present on admission)	3 (2.2)	13 (0.32)	< 0.001[a]
Opioid dependence or long-term use	11 (8.0)	124 (3.0)	0.004[a]
Psychiatric disease (present on admission)	65 (47.5)	1185 (28.9)	< 0.001[a]
Anesthesia type			1
General	136 (99.3)	4052 (98.7)	
Other	0 (0)	8 (0.2)	
Missing	1 (0.7)	47 (1.1)	
Patient-controlled analgesia			1
Epidural	0 (0)	18 (0.4)	
IV	136 (99.3)	3968 (96.6)	
Missing	1 (0.7)	121 (3.0)	
Received diazepam			< 0.001[a]
Yes	34 (24.8)	476 (11.6)	
No	103 (75.2)	3630 (88.4)	
Missing	0 (0)	1 (0.02)	
CT, MRI or both performed			0.26
Yes	136 (99.3)	3999 (97.4)	
No	1 (0.7)	107 (2.6)	
Missing	0 (0)	1 (0.02)	
ASA score			< 0.001[a]
1	1 (0.7)	214 (5.2)	
2	78 (56.9)	2974 (72.4)	
≥ 3	57 (41.6)	871 (21.2)	
Missing	1 (0.7)	48 (1.2)	

[a]$P < 0.05$. POD: Postoperative delirium; ASA: American society of anesthesiologists; CT: Computed tomography; MRI: Magnetic resonance imaging; BMI: Body mass index; SD: Standard deviation.

Table 6 Perioperative risk factors and adjusted association with postoperative delirium by procedure

	THAOR (95%CI), *n* = 18276	THA *P* value	TKAOR (95%CI), *n* = 19987	TKA *P* value	SFOR (95%CI), *n* = 4183	SF *P* value
Age, yr						
≥ 70 *vs* < 70	4.9 (3.0, 7.9)	< 0.001[a]	2.16 (1.58, 2.94)	< 0.001[a]	-	-
≥ 65 *vs* < 65	-	-	-	-	2.76 (1.79, 4.25)	< 0.001[a]
Male	0.90 (0.60, 1.35)	0.62	0.82 (0.60, 1.12)	0.21	0.73 (0.48, 1.10)	0.13
BMI	0.94 (0.90, 0.98)	0.004[a]	0.99 (0.96, 1.02)	0.37	0.99 (0.95, 1.02)	0.46
Latest creatinine value before surgery						
1.2-2.0 mg/dL *vs* < 1.2 mg/dL	1.77 (1.05, 3.00)	0.03[a]	0.79 (0.49, 1.27)	0.32	1.40 (0.73, 2.68)	0.31
> 2.0 mg/dL *vs* < 1.2 mg/dL	4.08 (1.06, 15.66)	0.04[a]	1.39 (0.46, 4.20)	0.56	2.26 (0.20, 26.24)	0.51
Preoperative hyponatremia	2.36 (1.54, 3.64)	< 0.001[a]	1.25 (0.87, 1.79)	0.23	1.24 (0.82, 1.88)	0.31
PCA route						
IV *vs* Epidural	1.98 (1.19, 3.28)	0.008[a]	1.26 (0.83, 1.92)	0.27	-	-
Peripheral nerve infusion *vs* Epidural	-	-	0.93 (0.47, 1.86)	0.85	-	-
Postoperative thiamine order	5.05 (2.72, 9.37)	< 0.001[a]	6.40 (4.00, 10.26)	<0.001[a]	6.64 (3.72, 11.85)	<0.001[a]
ASA Score						
2 *vs* 1	-	-	1.91 (0.26, 13.88)	0.52	1.90 (0.25, 14.19)	0.53
> 3 *vs* 1	-	-	3.63 (0.49, 26.74)	0.21	2.38 (0.31, 18.46)	0.41
≥ 3 *vs* 2	2.01 (1.33, 3.05)	< 0.001[a]	-	-	-	-
Anesthesia type						
Other *vs* general	2.92 (0.66, 12.85)	0.16	0.89 (0.43, 1.82)	0.74	-	-
Surgery length	1.00 (1.00, 1.01)	0.10	1.00 (0.99, 1.01)	0.55	1.00 (1.00, 1.00)	<0.001[a]
Atrial fibrillation, present on admission	0.97 (0.53, 1.77)	0.91	1.93 (1.32, 2.81)	<0.001[a]	2.19 (1.09, 4.41)	0.03[a]
Pressure ulcers, present on admission	0.65 (0.08, 5.05)	0.68	-	-	7.56 (1.89, 30.24)	0.004[a]
Opioid dependence or long-term use	7.11 (3.26, 15.51)	< 0.001[a]	2.98 (1.38, 6.41)	0.005[a]	1.88 (0.91, 3.90)	0.09
Parenteral diazepam	5.05 (1.5, 16.97)	0.009[a]	4.40 (1.52, 12.75)	0.007[a]	2.17 (1.19, 3.97)	0.01[a]
Elixhauser comorbidity						
Deficiency anemias	1.64 (0.74, 3.63)	0.22	1.10 (0.57, 2.11)	0.78	1.11 (0.42, 2.93)	0.83
Congestive heart failure	2.35 (0.93, 5.96)	0.07	1.59 (0.74, 3.38)	0.23	1.54 (0.39, 6.11)	0.54
Rheumatoid arthritis/collagen vascular diseases	1.06 (0.45, 2.51)	0.900	0.35 (0.13, 0.94)	0.04[a]	1.02 (0.49, 2.13)	0.95
Chronic pulmonary disease	1.13 (0.67, 1.92)	0.64	0.84 (0.55, 1.28)	0.41	1.06 (0.65, 1.73)	0.82
Coagulopathy	1.32 (0.39, 4.53)	0.66	1.60 (0.70, 3.62)	0.26	2.80 (1.05, 7.50)	0.04[a]
Depression	1.70 (1.05, 2.75)	0.03[a]	1.47 (1.02, 2.11)	0.04[a]	2.61 (1.73, 3.92)	<0.001[a]
Diabetes w/o chronic complications	1.54 (0.90, 2.64)	0.12	1.90 (1.36, 2.66)	< 0.001[a]	1.54 (0.92, 2.58)	0.10
Diabetes w chronic complications	2.05 (0.45, 9.23)	0.35	1.77 (0.68, 4.58)	0.24	3.34 (1.02, 10.91)	0.046[a]
Hypertension	1.62 (1.06, 2.48)	0.03[a]	1.21 (0.59, 1.64)	0.23	1.00 (0.66, 1.51)	0.99
Hypothyroidism	1.01 (0.61, 1.66)	0.98	1.46 (1.06, 2.02)	0.02[a]	1.07 (0.65, 1.76)	0.80
Liver disease	0.41 (0.05, 3.22)	0.40	0.70 (0.16, 3.07)	0.63	0.71 (0.15, 3.30)	0.66

Lymphoma	1.33 (0.25, 7.20)	0.74	-	-	-	-
Fluid and electrolyte disorders	0.31 (0.04, 2.43)	0.26	1.41 (0.44, 4.56)	0.57	1.14 (0.36, 3.63)	0.82
Other neurological disorders	2.04 (0.98. 4.27)	0.06	2.79 (1.69, 4.60)	< 0.001[a]	2.14 (1.10, 4.14)	0.02[a]
Obesity	1.06 (0.53, 2.12)	0.88	0.79 (0.53, 1.19)	0.27	1.56 (0.90, 2.69)	0.11
Peripheral vascular disorders	1.20 (0.47, 3.10)	0.70	1.40 (0.62, 3.16)	0.42	1.68 (0.64, 4.42)	0.30
Psychoses	2.52 (0.81, 7.90)	0.11	6.39 (3.51, 11.62)	< 0.001[a]	4.95 (2.38, 10.28)	<0.001[a]
Pulmonary circulation disorders	1.20 (0.47, 3.10)	0.70	1.69 (0.89, 3.23)	0.11	1.57 (0.51, 4.88)	0.44
Renal failure	0.94 (0.41, 2.15)	0.88	2.32 (1.31, 4.11)	0.004[a]	0.97 (0.39, 2.45)	0.95
Solid tumor w/o metastasis	-	-	1.42 (0.31, 6.45)	0.65	-	-
Valvular disease	1.08 (0.59, 1.97)	0.80	1.23 (0.79, 1.92)	0.37	1.17 (0.61, 2.26)	0.63
Weight loss	0.61 (0.05, 7.46)	0.70	7.14 (0.62, 82.11)	0.11	-	-

[a]$P < 0.05$. POD: Postoperative delirium; THA: Total hip arthroplasty; TKA: Total knee arthroplasty; ASA: American society of anesthesiologists; PCA: Patient-controlled analgesia; SF: Spine fusion surgery; CI: Confidence interval; BMI: Body mass index; OR: Odds ratio.

ARTICLE HIGHLIGHTS

Research background

Postoperative delirium (POD) is one of the most common complications in older adult patients undergoing elective surgery. The reported incidence ranges from 3%-25% after elective surgery. Many perioperative characteristics have been associated with the development of POD including increased length of recovery and hospital stay, as well as increased morbidity and mortality. Fixed risk factors often associated with POD include advanced age, pre-existing central nervous system deficits, psychiatric disease, alcohol abuse, emergency surgery and the presence of multiple comorbidities.

Research motivation

Delirium is one of the most common complications in older adult patients undergoing elective surgery. Few studies have compared, within the same institution, the type of surgery, risk factors and type of anesthesia and analgesia associated with the development of delirium.

Research objectives

We investigated the following three questions: (1) What is the incidence of POD after non-ambulatory orthopedic surgery at a high-volume orthopedic specialty hospital?; (2) Does surgical procedure influence incidence of POD after non-ambulatory orthopedic surgery?; and (3) For POD after non-ambulatory orthopedic surgery, what are modifiable risk factors?. Exploring these questions will help us determine how to treat patients at higher risk for POD when undergoing an orthopedic procedure.

Research methods

Common epidemiological research methodology and statistical analyses were used in this investigation. Electronic health records were collected and preliminary descriptive statistical analysis were conducted. Frequency counts and percentages for discrete variables and median, intra-quartile range, and minimum and maximum values for continuous variables were reported. Crude inferential analysis consisted of Chi-square and Fisher Exact tests for discrete comparisons and independent samples *t*-tests for continuous variables. When continuous variables failed to meet the assumption of normality using the Kolmogorov-Smirnov test, non-parametric Mann Whitney U tests were used in place of *t*-tests. Multivariable logistic regression analysis was used to identify potential risk factors POD while adjusting for any potential confounding.

Research results

Of 78492 surgical inpatient surgeries, the incidence from 2009 to 2014 was 1.2% with 959 diagnosed with POD. The incidence of POD was higher in patients undergoing spinal fusions (3.3%) than for patients undergoing total hip arthroplasty (THA) (0.8%); THA patients had the lowest incidence. Also, urgent and/or emergent procedures, defined by femoral and pelvic fractures, had the highest incidence of POD (7.2%) than all other procedures. General anesthesia was not seen as a significant risk factor for POD for any procedure type; however, IV patient-controlled analgesia (PCA) was a significant risk factor for patients undergoing THA [Odds ratio (OR) = 1.98, 95% confidence interval (CI): 1.19 to 3.28, $P = 0.008$]. Significant risk factors for POD included advanced age (for THA, OR = 4.9, 95%CI: 3.0 to 7.9, $P < 0.001$; for total knee arthroplasty (TKA), OR = 2.16, 95%CI: 1.58 to 2.94, $P < 0.001$), American Society of

Anesthesiologists (ASA) score of 3 or higher (for THA, OR = 2.01, 95%CI: 1.33 to 3.05, $P < 0.001$), multiple medical comorbidities, hyponatremia (for THA, OR = 2.36, 95%CI: 1.54 to 3.64, $P < 0.001$), parenteral diazepam (for THA, OR = 5.05, 95%CI: 1.5 to 16.97, $P = 0.009$; for TKA, OR = 4.40, 95%CI: 1.52 to 12.75, $P = 0.007$; for spine fusion, OR = 2.17, 95%CI: 1.19 to 3.97, $P = 0.01$) , chronic opioid dependence (for THA, OR = 7.11, 95%CI: 3.26 to 15.51, $P < 0.001$; for TKA, OR = 2.98, 95%CI: 1.38 to 6.41, $P = 0.005$) and alcohol dependence (for THA, OR = 5.05, 95%CI: 2.72 to 9.37, $P < 0.001$; for TKA, OR = 6.40, 95%CI: 4.00 to 10.26, $P < 0.001$; for spine fusion, OR = 6.64, 95%CI: 3.72 to 11.85, $P < 0.001$). Many of the risk factors identified have been cited in previous reports and are not amenable to modification: advanced age, medical comorbidities, and a history of psychiatric disease. However, some risk factors such as pre-existing narcotic dependence, alcoholism, and hyponatremia are potentially modifiable. In addition to surgical procedure, type of anesthesia and type of postoperative analgesia may affect the incidence of POD and as such be targeted in an attempt to reduce the incidence of POD.

Research conclusions

The incidence of POD reported in this study is lower than what has been reported in many previous studies. Even in patients greater than 70 years old, our reported incidence of 2.5% is considerably below the reported rates of 15%-20% after elective surgery and 50% after the repair of hip fractures. The incidence of delirium varied between the various non-ambulatory surgical procedures. Pelvic and hip fractures demonstrated the highest rate followed by spinal fusions and then knee arthroplasty. Patients undergoing TKA are older, generally have more pain, increased comorbidities, lose more blood with subsequent increased intravenous fluid infusions, and are hospitalized longer at our institution than those undergoing THA. All of these factors could have contributed to an increase in POD. We did not find arthroplasty patients undergoing general anesthesia had a higher risk of POD than patients who received a regional anesthetic. However, this difference was present in the type of postoperative analgesia received for THA patients; epidural PCA versus intravenous PCA. We found that preoperative narcotic dependence was a major risk factor for the development of POD for THA, TKA and spine fusion patients. Opioid-tolerant patients require higher doses of postoperative opioids, and their pain is more difficult to control. The administration of postoperative opioids, particularly intravenous PCA, has been associated with sleep disturbances, cognitive impairment, and delirium. Some studies have also suggested an association between ketamine administration and postoperative confusion. However, perioperative administration of ketamine is often used to manage chronic pain in patients and reduce narcotic requirements. Hence, a direct association between ketamine and delirium is inconclusive. In this study and others, the postoperative administration of diazepam was associated with the development of POD. Diazepam is not utilized at this institution to treat postoperative confusion, but is instead used to treat anxiety or to prevent benzodiazepine withdrawal. Entering surgery as an opioid tolerant patient significantly increases the risk of POD and all efforts should be aimed at reducing the preoperative narcotic requirements of these patients and a postoperative analgesic protocol which emphasizes a non-narcotic approach should be used. For those patients at risk for POD a multifactorial intervention approach which includes multi-modal analgesia which de-emphasizes opioids, a reduction in the administration of psycho-active medications, preoperative alcohol use counselling and abstinence, early postoperative ambulation and possible early intervention with dexmedetomidate or atypical anti-psychotic medications is recommended for patients undergoing elective orthopedic inpatient surgery.

Research perspectives

We hypothesized that regional anesthesia, postoperative opioid sparring techniques, and early ambulation were responsible for the lower incidence of POD in our arthroplasty patients. Future research may involve a program designed for elderly patients at risk for POD undergoing total joint arthroplasty and should include: A regional anesthetic with reduced intravenous sedation; when feasible, local anesthetic blocks for postoperative analgesia; opioid sparring medications including acetaminophen and nonsteroidal anti-inflammatory drugs; time and place orienting by nursing staff; undisturbed sleep while in the hospital; and early ambulation and discharge from the hospital. The incidence of POD in this group should then be compared to controls. The spine fusion patient population, which has a higher incidence of POD, could also be used in future research studies using the postoperative protocol designed for arthroplasty patients outlined above with an alteration to the anesthetic protocol. Spine fusion patients require general anesthesia – in these procedures rather than using a regional anesthetic or local anesthetic block, the general anesthesia can be administered to reduce the patient's exposure to medications that have the potential to produce delirium. The anesthetic can include intravenous dexmedetomidate, lidocaine and ketamine, all of which will reduce narcotic administration. Furthermore, since preoperative narcotic dependence was associated with POD, future research should also focus on preoperative opioid reduction and clear postoperative pain management expectations.

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Observational Study

Epidemiology and injury patterns of aerial sports in Switzerland

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Abstract

BACKGROUND

Airborne sports have become more popular in recent years. The number of accidents has increased linearly as athletes take increasingly greater risks to experience the adventurous spirit of this kind of sports.

AIM

To investigate the variety of injuries in airborne sport accidents, as well as which acute treatment these patients receive, both before and after admission to a level-one-trauma center.

METHODS

We performed a retrospective chart analysis at a major level-one-trauma center in Switzerland for 235-patients who were admitted following airborne sports injuries between 2010 and 2017. Patients' demographic data, injury patterns, emergency primary care procedures and intra-hospital care were recorded.

RESULTS

Overall, 718-injuries in 235-patients were identified; the spine was the most commonly affected region with 46.5% of injuries (n = 334/718) in 143-patients. In 69-patients (15.5%), the (non-spine) thorax was affected, followed by the lower and upper extremity, pelvis, head/face and abdominal injuries. Eleven-patients had to be intubated at the trauma site. Three patients were resuscitated after onset of pulseless-electrical-activity. Two-patients died in the resuscitation room.

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In 116-cases, surgery was indicated including 55-emergency surgeries. Another 19 patients (8.1%) were transferred to the intensive care unit.

CONCLUSION
Paragliders are most commonly affected, although the highest injury severities were identified for Building, Antenna, Span and Earth-jumping athletes. First responders, treating physicians and pilots should be aware of the risk for potentially serious and life-threatening injury with an in-hospital mortality of 0.9%.

Key words: Airborne sport; Sport injuries; Trauma; Spine; Pelvis; Emergency medicine; Paragliding; Parachuting; Delta-flying

Core tip: We describe the different severities and types of injuries in individual airborne sports in one cohort. This study will improve the pre- and intra-/hospital management especially in the emergency department to accelerate and simplify the diagnostics and allow prompt and early initiation of the treatment. Furthermore, pilots will be more aware of injuries and injury patterns, which may help to develop new prevention programs.

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INTRODUCTION

Due to Switzerland's mountainous landscape, many different airborne sports [Paragliding, skydiving, Building, Antenna, Span and Earth (BASE)-jumping, Delta flying and speed flying] are commonly performed. One of the most popular and famous venues for these sports is Lauterbrunnen (Berne, Switzerland), where about 15000 jumps and flights are performed annually[1].

The most common airborne sport in Switzerland is paragliding, a sport that requires a delicate and deft touch to maintain appropriate balance even in calm conditions. Paragliding can become exponentially less safe and more difficult in more turbulent weather conditions. Due to its popularity in Switzerland, the Swiss Paragliding Association was established in 1974 with about 15200 members currently registered[2]. Paragliding is responsible for the highest number of injuries amongst these types of sports, especially during the launching and landing phase with mortality rates up to 22% described. In Switzerland, 13.7% of paragliding pilots were severely injured (54/398) when performing paragliding between 2013 and 2017[2-4]. Spine injuries are the most commonly reported injuries, followed by talus and calcaneus fractures[1,5]. Other extreme sports include skydiving, BASE jumping, parachuting and Speed flying. In skydiving approximately 5.5 million jumps in over 40 countries were recorded in 2009. In BASE jumping pilots require a wingsuit, which can aerodynamically be controlled by the body, and a parachute for landing[6,7]. Speed flying on the other hand is comparable to paragliding where pilots try to keep up in the air as long as possible with a high risk of severe injuries due to higher speed[8,9]. The orthopaedic and trauma literature have a relative dearth of information on injuries that can result from these extreme sports.

Therefore, the aim of this study is to investigate (1) the pre- and in-trauma-center management of these potentially high impact injuries; (2) the severity of injuries based on the injury severity score; and (3) the different injury patterns according to the different types of airborne sports.

MATERIALS AND METHODS

After local ethic approval, we performed a retrospective chart analysis on all patients admitted to a single trauma-center between February 2010 and May 2017. Our emergency department database was searched for airborne sport injuries. Patients who got re-admitted because of a complication after primary treatment in another center or abroad were excluded from this study.

The emergency department at our university hospital is a level I trauma center with a commuter area of about 1.5 million people. Approximately 45000 trauma patients are treated there every year. The database provides information on basic demographics, the means of admission (*i.e.*, ambulance, air ambulance or self-admission) and in hospital acute care unit (such as resuscitation room or normal emergency department), diagnosis and co-morbidities, status of consciousness (GCS-Score), primary/secondary survey according to advanced traumatic life support protocol, as well as diagnostics performed. The short-term outcome was recorded by further procedures performed (discharged/outpatient, inpatient, transferred to intensive care unit (ICU), emergency surgery, early elective surgery or no surgical procedures).

To classify the injury severities, we used the injury severity score (ISS)[10]. Therefore, the injuries were summarized according their location to upper and lower extremity, thoracic, abdominal trauma, spine, pelvis and head/face injuries using the abbreviated injury codes as has been done previously[11]. All data are presented in absolute numbers and percentages.

We used Microsoft Excel spreadsheet and Origin Lab, using a *t*-test for mean and standard deviation for all calculations and graphs. Statistical significances are expressed as $P < 0.05$, $P < 0.01$ and $P < 0.005$.

RESULTS

Demographics

A total of 237 patients suffering from airborne injuries were admitted to the emergency department between February 2010 and June 2017. Two patients were readmitted due to complications after the previous hospitalization. These patients were excluded due to missing acute trauma care data, leaving 235. In most cases paragliding ($n = 192$; 82.6%; including 13 tandem-Paraglider) was the cause of injury, followed by BASE-jumping ($n = 25$), skydiving ($n = 10$; one tandem-skydiver), speed flying ($n = 4$) and finally Delta flying ($n = 2$) as shown in Table 1. The mean age was 38.7 years (Min/Max 18 - 74) with a predominance in male 198 (84.3%) patients and a mean injury severity score of 16.5 (SD 14, range from 0 to 75). However, this varied according to the airborne sport performed. For BASE-jumping the ISS was higher although no significance was identified ($P = 0.1$).

Prehospital management and admission

In total, 11 patients had to be intubated at the trauma site by the prehospital emergency physician (4.7%). One hundred fifty-five patients (67.0%) were admitted by air rescue. Sixty-two of these patients' (68.9%) primary diagnostics were performed in the resuscitation room and in three cases a manual resuscitation was required due to onset of a pulseless electrical activity. Two of these patients died. One had a severe pelvis fracture, femoral fracture with liver laceration and haemo-pneumothorax, whereas the other patient suffered from a severe cranio-cerebral injury. In both cases, only whole body low dose X-ray was performed without a computed tomography. The overall intra-hospital mortality in our cohort was 0.9%. Our database does not include the pre-hospital mortality. All details of the type of admission and airborne sport details are summarized in Table 1.

Epidemiology of injuries

Two hundred thirty-five patients suffered 718 injuries (mean 2.8 injuries/per patient). The most commonly affected location was the spine within 143 patients (143/235, or 60.9%) and in total 334 individual spine injuries (334/718, or 46.5%), followed in incidence by thorax injuries (69/235, or 29.4%). The most commonly affected vertebral body was L1 (68/334, or 20.4%), followed by L2 (47/334, or 14.1%). Neurologic impairment was identified in 31 patients accompanied by spinal injury (31/143, or 21.7%); seven type A, two type B, seven type C (including cauda equina syndrome), 15 type D according to ASIA grading. Most injuries were defined as serious with a mean abbreviated injury code of 2.77. In patients who suffered from thorax injuries the most commonly affected organ was the lung – including lung laceration, lung

Table 1 Distribution of different airborne sports, injury severity score, age, type of admission and primary trauma care unit, *n* (%)

	Overall	Paragliding	BASE-jumping	Skydiving	Delta flying	Speed flying
Total numbers	235 (100)	194 (82.6)	25 (10.6)	10 (4.2)	2 (0.9)	4 (1.7)
Male	198 (84.3)	162 (83.5)	23 (92)	9 (90)	2 (100)	2 (50)
Injury severity score, *n* (SD)	16.5 (14.0)	16.0 (13.9)	21.1 (13.9)	13.3 (15.2)	18 (14)	19.75 (8.8)
Age (yr, range)	38.7 (18-74)	39.8 (18-74)	30.8 (21-45)	37.2 (20-59)	51 (49-53)	33.3 (27-45)
Air rescue	155 (67.0)	129 (66.5)	19 (76.0)	2 (20.0)	1 (50)	4 (100)
Ambulance	6 (2.6)	5 (2.6)	1 (4.0)	-	-	
Self-admission	28 (11.9)	21 (10.8)	1 (4.0)	5 (50.0)	1 (50)	-
Transferred from other hospitals	44 (18.7)	37 (19.1)	4 (16.0)	3 (30.0)	-	-
Not otherwise specified	2 (0.9)	2 (1.0)	-	-	-	-
Resuscitation room	162 (68.9)	133 (68.6)	21 (84.0)	3 (30.0)	1 (50)	4 (100)
Normal trauma ward	72 (30.6)	60 (30.9)	4 (16.0)	7 (70.0)	1 (50)	-
Not otherwise specified	1 (0.4)	1 (0.5)	-	-	-	-

BASE: Building, Antenna, Span and Earth.

contusion or edema (32/69, or 46.4%), followed by rib fractures (17/69, or 24.6%). Fifteen subjects suffered from cardiac contusion, sternum fracture, or thoracic skin burning. With respect to abdominal injuries (23/235, or 9.8%), the most common injured organ was the liver (11 cases (47.8%). Other abdominal organs were less commonly damaged (Figure 1). For ISS both thorax and abdomen were serious, although the mean code was higher for abdomen with 3.18 than thoracic with 3.04.

The extremities were injured at a high rate as well, with 122 (51.9%) patients in total. The lower extremity (65/235, or 27.7%) had a few more injuries than the upper extremity (57/235, or 24.3%). The ankles were the most commonly fractured individual part of the extremities (16/122, or 13.1%), followed by femoral fractures in 15 (12.3%) patients. Four (3.3%) patients suffered from combined fractures of the lower extremity. The individual types of injuries are summarized in Figure 1. All injuries were defined as moderate with an abbreviated injury codes (AIC) of 2.09 for the upper and 2.34 for the lower extremities.

The sacrum and pelvis were fractured in 52 cases. Most of the injuries were combined sacro-pelvic fractures (33/52, or 63.5%), followed by isolated sacral (11/52, or 21.2%) and pelvic fractures (8/52, or 15.4%). Hereby, the highest AIC was observed among all locations with severe injuries and a mean AIC of 3.52. Finally, when looking at the face and head trauma we observed 48 patients (48/235, or 20.4%) with 52 injuries. The most common type of injuries were intracranial bleeds which occurred in 16 patients (16/48, or 33.3%), followed by concussions (15/48, or 31.3%). Skull fractures were present in nine patients (18.8%). The mean AIC was 2.57 and therefore defined as serious. All individual injuries and the percentages are summarized in Figure 1. Table 2 and Table 3 gives an overview of the distribution of injuries according to the different airborne sports, respectively the abbreviated injury codes among location of injuries.

Interventions

After performing the primary assessment at the emergency department, 15 chest tubes and three invasive intracranial pressure sensors were inserted in the resuscitation room. Emergency surgery was immediately indicated in 55 patients (55/235, or 23.4%, Table 4). Sixty-one patients (61/235, or 26.0%) underwent surgery in the following days. Nineteen patients were transferred to the intensive care unit (19/235, or 8.1%), in addition to 55 patients who underwent emergency surgery and were observed in the intensive care unit (55/235, or 23.4%). Furthermore, 111 patients were hospitalized on the general ward (111/235, or 47.2%) and in total, 47 patients were treated as outpatient (47/235, or 20%) and were discharged from the emergency department within 24 hours. In terms of injury severity score, the ISS was significantly higher for the emergency surgery group (22.9) and the intensive care unit group (24.8) compared to all other patients (13.3; both $P < 0.005$).

For the patients who were transferred from the resuscitation room to the operating room it took 2:34 h in mean respectively 4:18 h to the ICU.

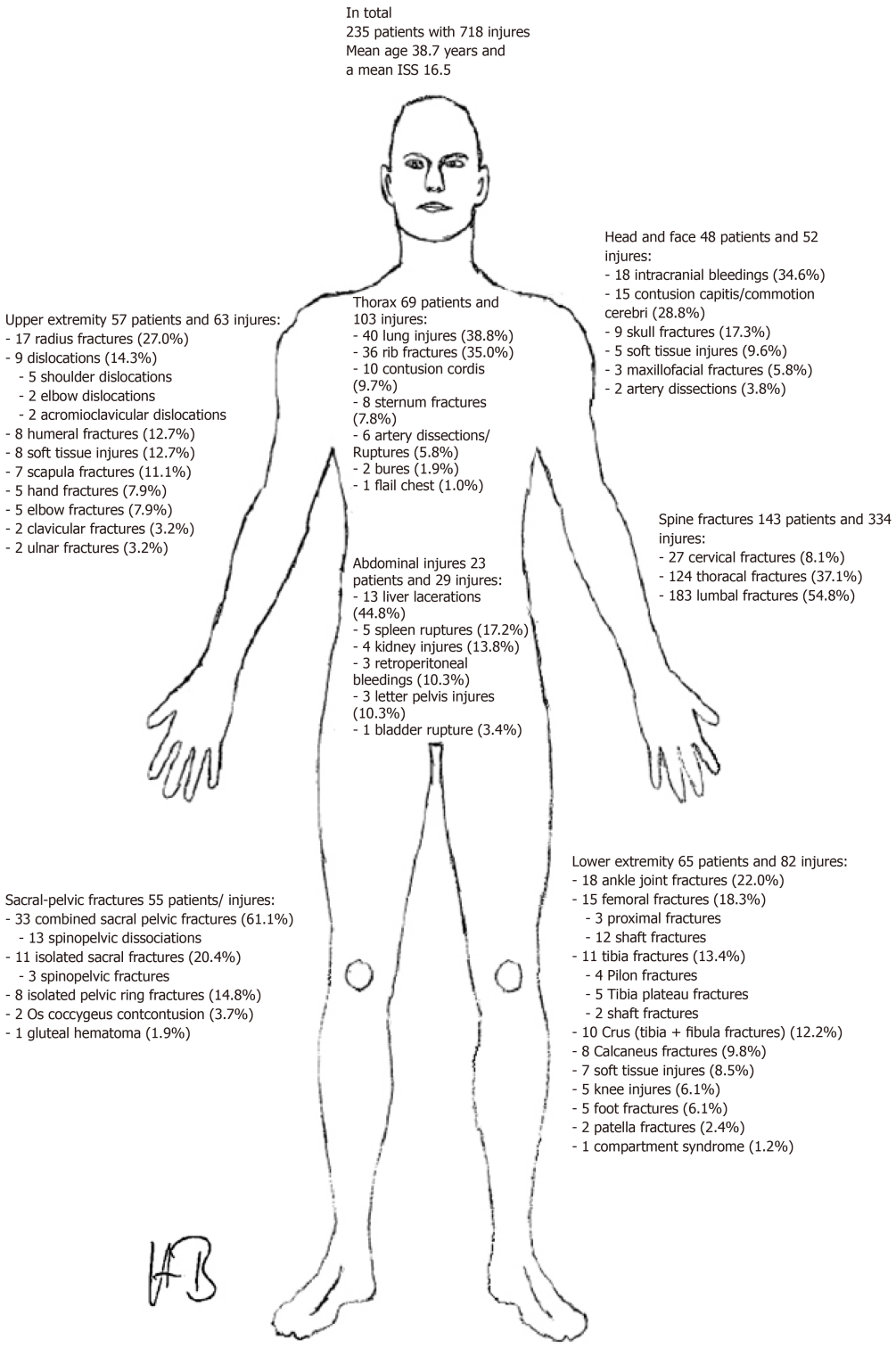

Figure 1 Distribution of injuries.

DISCUSSION

In the literature, the mortality rate was found to be approximately 45/100000 paragliding jumps[12] with one fatality in every 2317 BASE-jumps of which all deaths occurred on the scene and were not admitted to a hospital[13]. Since January 2013, all deaths of pilots who crashed during paragliding are reported to the Swiss Paragliding Association. Less severe injuries from paragliding incidents are reported by the pilots on a voluntary basis, and so it is very possible that the real incidence of injury is even higher than is recognized here. Furthermore, no equivalent register for skydiving, BASE-jumping, speed flying or Delta flying exists[2]. From about 15000 members of the Swiss paragliding association only 398 pilots reported an accident while paragliding

Table 2 Distribution of injuries according to the anatomic region in different airborne sports, *n* (%)

	Total	Spine	Extremity	Sacro/pelvis	Abdomen	Thorax	Head/face
Paragliding	532 (74.1)	274 (51.5)	92 (17.3)	41 (7.7)	22 (4.1)	66 (12.4)	37 (7.0)
BASE-jumping	134 (18.7)	48 (35.8)	33 (24.6)	12 (9.0)	5 (3.7)	26 (19.4)	10 (7.5)
Parachuting	20 (2.8)	1 (5)	10 (50)	2 (10)	1 (5)	2 (10)	4 (20)
Speedflying	24 (3.3)	11 (45.8)	2 (8.3)	-	1 (4.2)	9 (37.5)	1 (4.2)
Delta	8 (1.1)	-	8 (100)	-	-	-	-
Total	718 (100)	334 (46.5)	145 (20.2)	55 (7.7)	29 (4.0)	103 (14.4)	52 (7.2)

BASE: Building, Antenna, Span and Earth.

between 2013 and 2017. Most of them had no injury (128/398, or 32.2%), while one third had severe injuries (125/398, or 31.4%). Unfortunately, there were 54 fatalities from paragliding over this time period[2]. The 'BFU – Swiss Council for Accident Prevention' has given a total number of 132 flying sports related deaths from 2010 to 2016 for the whole of Switzerland with a mean of 19 patients per year. In 2015 eight pilots died when paragliding, and three when skydiving[14]. However, this data is not stratified regionally, thus we cannot correlate these data to our regional data. In our cohort, the overall intra-hospital mortality was 0.9% (n = 2; both paraglider), although our database does not include the pre-hospital mortality. Three patients had to be resuscitated due to onset of a pulseless electrical activity; only one survived.

Regarding the severity of injury related to the different sports, the most severe injuries were identified in BASE-jumping athletes as assessed by the injury severity score, followed by speed FLYING, Delta flying and paragliding. Our data show that less severe injuries are related to Skydiving among the cohort that was admitted alive to the hospital, although only ten patients were skydiving at the time of injury. For location, the pelvis was at greatest risk followed by the abdomen and thorax, which showed the highest abbreviated injury codes.

Emergency surgery and/or transfer to the intensive care unit was necessary in 55 cases (23.4%). In those patients who suffered from pelvis fractures, plate fixation was performed as all of them were medically stable. After adequate surveillance, 47 patients were treated as outpatient (20%) and were discharged within 24 h. It took a mean 2:34 h to transfer the patients from the resuscitation room to the operating room versus 4:18 h to the ICU. According to the German Trauma society register, in 2016, the mean time between initial assessment and emergency surgery was slightly higher in our center, compared with the average time in German clinics (1:14 h ± 0:59 h), likewise the transfer from the resuscitation room to the intensive care unit (1:22 h ± 1:12 h)[15].

This study also shows the importance of the prehospital management in assessing and treating the most severe, life-threatening injuries. Overall, 11 patients were intubated at the site of the accident. There is a well-established air rescue system with an emergency physician on board in Switzerland, which allows early rescue and admission to the hospital while providing maximal pre-hospital treatment, which potentially increases the survival rate. However, according to the air rescue database, only a small percentage (4.9%, or 544/11,055 in 2016) of helicopter missions in total are related to traumatic injuries. This emergency rescue setting may also explain a far lower death rate compared to data from another country (22%)[4,16]. In our subjects, more than half of the cases – 67.0% - were admitted by air ambulance and most patients got admitted through the resuscitation room – 68.9% - to avoid any delay for primary diagnostics and early onset of treatment according to advanced traumatic life support guidelines.

Comparing the injury patterns with those published in the literature, we see that the spine is by far more often affected in our cohort - especially paragliding (51.5%) and speed flying pilots (45.8%)[17,18]. The second most common location was the thorax, followed by the lower extremity. This difference may be related to the fact that skydivers usually hang in the parachute, whereas paragliders sit and most of the cases in our cohort were paragliders (82.6%). Ball *et al*[18] reported in their cohort, that the lower extremity was affected most (65%) followed by the head (22%) and spine (22%). This orientation of the body may also explain the high incidence of sacral-pelvic injuries due to the higher percentage of paragliders in our cohort compared to others[18]. Interestingly, in previous reports, injuries in those who performed BASE-jumping and survived were generally minor from a musculoskeletal perspective, including sprained ankles or knees, with only few moderate injuries, although

Table 3 Distribution of three most severe abbreviated injury codes by severity and location of injury

	Mean	1 -minor	2 - moderate	3 - serious	4 - severe	5 - critical	6 - maximal	Not within 3 most severe AIC	Total
Head/face	2.57	10	13	13	8	1	1	2	48
Thoracic	3.04	3	17	28	12	7	0	2	69
Abdomen	3.18	1	2	7	7	0	0	6	23
Spine	2.77	24	36	28	48	2	0	5	143
Pelvis	3.52	3	8	16	8	13	2	5	55
Upper extremity	2.09	7	29	11	0	0	0	10	57
Lower extremity	2.34	16	16	23	7	0	0	3	65

AIC: Abbreviated injury codes.

concussions were common[13,19]. Delta flyers suffer more from extremity injuries (100%). In parachuting the extremities (50%) are affected most, followed by the highest percentage of head and face injuries (20%). Our data show a shift towards more spine injuries than extremity injuries compared with the pre-existing literature[1].

Compared to other high energy trauma, like motorcycle injuries, the mean age in our group is slightly younger, 38.7 years versus 40.5 years from an historical cohort. The mean ISS is by far lower in an historical motorcycle injury cohort, 7.7 ± 6.7 *vs* 16.5 ± 14.0 and the most common types of injuries are rib fractures and maxillofacial trauma (2.5%, respectively 11.6%) according to Liang *et al*[20]. Rust *et al*[21] assessed the injury patterns of snowboarders and described that especially the lower and upper extremities are at risk, which include anterior cruciate ligament tears, distal radius fractures and knee sprains. Closed head injury is less likely, whereas only few lumbar strains without fractures were reported[21]. These injuries stand in contradistinction to those seen in airborne sports which affected mainly the spine with pelvis and lumbosacral junction and the thorax followed by extremities.

In the literature few publications on vascular injuries such as rupture or dissection exist – mainly as case reports[22], however according to our data it may be more common than suspected. In total, we identified eight vascular injuries – two dissections of the cranial vessels (vertebral artery, carotid artery), four aortic ruptures or dissections and one coronary artery dissection, combining for an incidence of 3.4%. This relatively high incidence may also be due to the strict full body computed tomography-scan done in high ISS-Scores, which has not historically been done.

When looking for the causes of paragliding injuries, about 53.5% are related to pilot errors, followed by weather conditions in 10.1%[23]. As the paragliding parachute is fragile, it may collapse and it is difficult to re-inflate and re-balance. In paragliding most common injuries occur during take-off which includes the running and inflation phase (35.1%) or landing (48.7%)[24,25]. Likewise in skydiving where a proper landing technique is pivotal to avoid injuries[18].

As Westman *et al*[17] stated for skydiving, general instructions for students to activate reserve parachutes should be given, even though in paragliding this may not help in most cases as most injuries occur during the start and landing phase from less height. In addition, training courses and special gliders (wider ones, which allow more stability) should be provided for beginners and for intermediate. To reduce the incidence of pelvic and sacral injuries, harnesses have become safer over time, due to new robust, replaceable Polyvinyl plastics as a protector. Once an accident has occurred, one of the most important parts in mitigating injury seems to be the level in life support training of the first responder, to identify severe injuries and reduce the risk of further complications from unnecessary or inappropriate movement.

Limitations

Shortcomings of this study are the retrospective, descriptive study design and the focus on patients who were admitted to the emergency department of a level-one-trauma-center. Patients with mono-trauma or less severe injuries may present to the general practitioner or were admitted to smaller hospitals, which therefore may be missed in our study. We are also not able to report the overall mortality, as some patients died before admission to the hospital. Furthermore, no information is given about the long-term survival rate and treatment outcome of severely injured patients presented in this cohort.

Table 4 Emergency surgery indications classified by the leading medical specialty, *n* (%)

	Emergency surgeries	Procedure
Total	55 (100)	
Extremities	18 (32.7)	10 external fixations, 4 plate osteosynthesis, 4 internal fixations with intramedullar nail
Open fractures	12	
Closed fractures	6	
Spine surgery	23 (41.8)	16 decompressions and pedicle screw fixation, 7 percutaneous stabilizations
With neurology	16 (69.6)	
Without neurology	7 (30.4)	
Pelvic fixation	7 (12.7), including one with Urinary bladder rupture	7 plate osteosynthesis and in one case direct suturing of the bladder
Vascular surgery	3 (5.5)	2 arterial bypasses, 1 coronary artery angiography
Others (visceral, plastic, neuro, maxillo fascial)	4 (7.3), each 1	1 explorative laparotomy, 1 debridement (after burn), 1 cerebral decompression, 1 maxillofacial fixation
Additionally interventions	15 thoracic trauma, 3 cerebral trauma	15 thoracic drainages, 3 ICP probe insertion

BASE: Building, Antenna, Span and Earth.

CONCLUSION

In conclusion, this study shows the clinical impact and severity of airborne injuries. In total, 235 patients suffered from paragliding, speed flying, Delta flying, skydiving or BASE-jumping injuries with a total of 718 injuries. More than half of the patients were admitted by the air ambulance and through the resuscitation room. Contrary to the literature, not the lower extremities but the spine and thorax were most commonly affected in our cohort. The overall intra-hospital mortality was 0.9%. Optimal treatment likely involves both maximizing safety on the front end to decrease the incidence of injury and continued vigilance to swiftly treat those that do get injured in order to minimize morbidity and mortality.

ARTICLE HIGHLIGHTS

Research background

Airborne sports are becoming more popular in recent years especially in Switzerland due to its landscape.

Research motivation

The number of accidents has increased linearly with the increased popularity as athletes take increasingly greater risks to experience the adventurous spirit of the sport. To assess potential changes in injury patterns over the years due to different trends and changes sports men mentalities.

Research objectives

Our purpose was to investigate the variety of injuries in airborne sport accidents, as well as what acute treatment these patients receive, both before and after admission to a trauma center.

Research methods

We performed a retrospective chart analysis at a major level-one-trauma center in Switzerland for patients who were admitted due to airborne injury between 2010 and 2017.

Research results

A total of 237-patients were admitted to our center, having suffered an airborne sport accident. Two patients were excluded as they were a readmission from a previous injury. Overall, 718-injuries in 235-patients were identified; the spine was the most commonly affected region with 46.5% of injuries (n = 334/718) in 143-patients. In 69-patients (15.5%) the (non-spine) thorax was affected, followed by the lower and upper extremity, pelvis, head/face and abdominal injuries. Eleven patients had to be intubated at the trauma site, three patients were resuscitated after onset of pulseless-electrical-activity. Two-patients died in the resuscitation room. In 116-cases, surgery was indicated including 55 emergency surgeries. Other 19-patients (8.1%) were transferred to the intensive care unit.

Research conclusions

There is a high potential for serious and sometimes life-threatening injuries in airborne sports.

Contrary to the current literature, the spine was the most commonly affected body region in our cohort and not lower extremities as cited before.

Research perspectives

Athletes, as well as first responders and ultimately the treating physicians, must be aware of the risk for potentially serious injury.

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CASE REPORT

Pseudotumor recurrence in a post-revision total hip arthroplasty with stem neck modularity: A case report

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Author contributions: Chimento GF was the patient's primary joint surgeon; Sumarriva GE analyzed and interpreted the imaging findings; Desai BR reviewed the literature and drafted the manuscript; Desai BR, Sumarriva GE, and Chimento GF were responsible for the revision of the manuscript for important intellectual content; all authors issued final approval for the version to be submitted.

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Abstract

BACKGROUND

This unique presentation of hip swelling is only the seventh reported case of pseudotumor recurrence in a non-metal-on-metal total hip arthroplasty (THA) construct. The constellation of patient symptoms and laboratory findings contradict the expected elevated serum metal ion levels associated with the formation of pseudotumor. The presentation, lab trends, and imaging findings contribute to the growing base of knowledge surrounding the effects of corrosion in arthroplasty constructs with stem-neck modularity.

CASE SUMMARY

A 74-year-old man status post primary THA presented with left hip swelling and elevated serum metal ions five years after implantation of a modular stem-neck prosthesis. The swelling was diagnosed as pseudotumor based on laboratory trends and imaging findings and was treated with revision arthroplasty that completely resolved the initial hip swelling. The patient presented with recurrent hip swelling and recurrent pseudotumor findings on imaging in the same hip four months later. Non-operative management with ultrasound-guided hip aspiration resulted in symptom relief and resolution of the recurrent swelling. After one year of follow-up, the patient had no further recurrences of hip swelling.

CONCLUSION

This case of post-revision pseudotumor recurrence elucidates attributable patient, surgical, and implant factors with a discussion of diagnostics, management, and prognosis for patients with pseudotumor in non-metal-on-metal arthroplasty constructs.

Key words: Revision arthroplasty; Pseudotumor; Stem-neck modularity; Pseudotumor recurrence; Metal-on-metal arthroplasty; Modular stem; Case report

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Core tip: This unique presentation of hip swelling is only the seventh reported case of pseudotumor recurrence in a non-metal-on-metal total hip arthroplasty construct. These patients require a low threshold for clinical evaluation, using multiple modalities such as history, physical exam, magnetic resonance imaging, and serum metal ion level testing. The presentation, lab trends, and imaging findings of this case contribute to the growing base of knowledge surrounding the effects of corrosion in arthroplasty constructs with stem-neck modularity.

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INTRODUCTION

Total hip arthroplasty (THA) yields excellent patient satisfaction and offers improvement in mobility and quality of life[1]. Advancements in technology have shaped prosthesis design to accommodate patient factors, level of activity, and surgical approaches. THA constructs can be composed of three components-the femoral component, acetabular component, and bearing surface. One variation of prosthesis design is modular neck systems, which allow a wide range of intraoperative adjustments of the femoral head, adjustment of leg length, and horizontal femoral offset [2]. Modularity aims to reproduce the natural biomechanics of the hip through the adjustment of individual prosthetic components. Proximal stem-neck modularity includes a junction that can have a double taper subjective to both axial and bending stresses. This stress leads to an uncommon complication known as fretting corrosion[2]. Destruction at contact sites from relative micromotion between two components of the prosthesis can lead to mid-stem failure in modular stem prostheses[2].

Metal-on-metal (MoM) THA is an alternative prosthetic design that was commonly used before unexpected complications led to its disuse. The concept was originally designed with the advantage of increased joint stability and fewer dislocations given a larger surface area for contact. An unforeseen complication of MoM arthroplasty was pseudotumor formation–at rates as high as 59% in studied cohorts[3]. This association has been seen consistently in metal-on metal THA[4]. A study by Ming showed the elapsed time between MoM THA and revision arthroplasty for pseudotumor formation to be 61 mo[5]. In the same study cohort of 97 patients, 3% had post-revision pseudotumor recurrence[5]. Recently, pseudotumor formation has been linked to non-metal-on-metal THA, especially in patients with modular constructs. Based on the literature review conducted by the authors of this report, only seven cases of pseudotumor recurrence have been associated in THA with non-MoM modular constructs[5,6].

The authors of this paper present a case of post-revision pseudotumor recurrence in a THA with a modular femoral component. The patient was informed that data concerning the case would be submitted for publication, and patient consent was obtained. Table 1 outlines a timeline of the patient presentation.

CASE PRESENTATION

Chief complaints

A 74-year-old African-American male was referred to the senior author on the orthopedic joint service with left hip swelling and pain more than five years after THA (Figures 1 and 2). The patient presented with a one-month history of left hip swelling. Associated symptoms included discomfort with movement, decreased range of motion, and left lower extremity swelling. There was no recent history of trauma and the left limb was neurovascular-intact.

Table 1 Patient timeline describing presentation, symptom progression, and clinical course

Timeline	Patient situation
February 2012	Past medical history: Degenerative osteoarthritis; Underwent left total hip arthroplasty
November 2017	Initial presentation for left hip swelling; Fluid collection seen on magnetic resonance imaging
December 2017	Treated with revision total hip arthroplasty; Immediate resolution of pseudotumor post-revision
March 2018	Recurrent left hip swelling; Resolution after repeat magnetic resonance imaging and joint aspiration
March 2019	After 1-yr of follow-up no further hip swelling recurrences or pain symptoms

History of presenting illness

The patient presented with left hip swelling and was evaluated with physical exam and imaging. Magnetic resonance imaging (MRI) showed a well-defined complex lesion anterior to the left hip prosthesis (Figure 3) and a septated simple fluid collection posterior to the left hip prosthesis; further evaluation revealed elevated serum metal ion levels-serum cobalt 12 ng/mL (ref. range 0.0-0.9 ng/mL) and serum chromium 2.8 ng/mL (ref. range < 0.3 ng/mL) The lesion was first unsuccessfully managed with aspiration by interventional radiology. After continued discomfort and signs of component loosening on imaging, the patient opted for with revision arthroplasty. During revision, the initial incision was used to resect necrotic soft tissue and drain a large blood-tinged fluid collection in the articular space. The collected tissue was sent for culture and pathology, which showed fibrin and fibrous tissue without the presence of neutrophils. On extraction of the head and neck, there was a significant degree of corrosion along the mid-portion and body of the neck. The acetabular component was well-fixed and in good condition to accommodate a new constrained liner. The revision was completed by extracting the proximal segment of the femoral stem and replacing it with an 18 mm × 155 mm modular stem, a 25-mm neutral proximal body, and 28 mm neutral femoral head. The new components were firmly seated, demonstrating stability and no impingement on range of motion. At two-week follow-up patient was ambulating well with a cane with no acute post-operative complications (Figure 4).

The patient presented again four months post-revision with a two-week history of recurrent left hip swelling. A new lesion was noted on MRI in a location similar to the initial lesion (Figure 5). Serum metal ion levels at this time had returned to baseline (serum cobalt = 1.5 ng/mL; serum chromium = 1.4 ng/mL). Ultrasound-guided fine needle aspiration of the lesion yielded 15cc of clotted blood, resembling the aspiration findings of the initial lesion suggesting adverse local tissue reaction (ALTR) recurrence.

History of past illness

The patient's only notable past medical history was hypertension well-controlled on medication.

Laboratory examinations

New pseudotumor formation in a location similar to the initial lesion was noted on MRI. Serum metal ion levels were elevated above the normal range, but significantly lower than on initial presentation for pseudotumor formation (serum cobalt = 1.5 ng/mL; serum chromium = 1.4 ng/mL).

Imaging examinations

MRI at time of initial presentation showed a well-defined complex lesion anterior to the left hip prosthesis and a septate simple fluid collection posterior to the left hip prosthesis. Repeat MRI at recurrence confirmed a similar lesion larger in size at the same location.

FINAL DIAGNOSIS

The final diagnosis of the presented case is post-revision ALTR recurrence.

TREATMENT

An ultrasound-guided hip aspiration provided symptomatic relief and resolution of hip swelling.

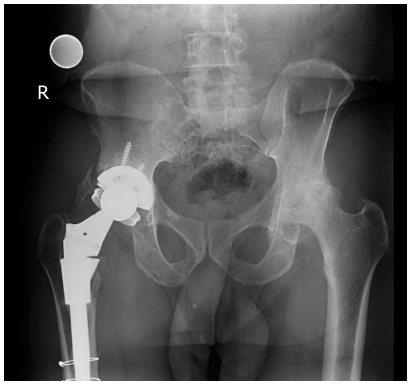

Figure 1 Pre-operative anterior-posterior pelvic radiograph showing degenerative changes of left hip with severe joint space narrowing, subchondral sclerosis, and cyst formation.

OUTCOME AND FOLLOW-UP

At clinical follow-up 18 mo post-revision there were no radiographic signs of implant loosening and the patient reported no further episodes of hip swelling with satisfactory return to baseline mobility.

DISCUSSION

The goal of prosthetic modularity is to offer intraoperative adjustments to manage leg length, anteversion, and offset to better replicate natural hip biomechanics[7]. Dual modularity refers to arthroplasty construct components (head, neck, and stem) that may be interchanged, specifically at the proximal portion where the head-neck and neck-stem junctions are located. Modularity at the head-neck junction was originally designed to allow movements in different planes and to reduce friction and wear[2]. However, the additional junctions pose complications such as fracture, corrosion, fretting, dissociation, and cold-welding[8]. The specific concern of fretting and crevice corrosion is a known association established in modular constructs[9]. Micromotion at the neck-stem junction from natural bending movements can predispose components to fretting corrosion and metal debris deposition[9].

Pseudotumor is a term historically associated with metal-on-metal arthroplasty implants. However, with the growing recognition that cystic masses causing pain, pressure effects, bone and soft-tissue destruction can be associated with implants of different bearings and degrees of modularity, the literature has adapted new terms such as asymptomatic lymphocytic vasculitis-associated lesions based on histological findings and the more encompassing term ALTR. A recent systematic review of pseudotumors suggested an incidence ranging from 1% up to 6% of all hip THAs[4]. These pseudotumors are neither infective nor neoplastic and have been proposed to occur secondary to excessive wear debris, foreign body reaction, metal hypersensitivity, and certain patient/surgical-related factors[6].

One commonly suggested etiology of ALTRs is metal ion deposition generated by mechanical wear and surface corrosion at modular junctions[10]. Fretting is a relative oscillatory tangential movement of small amplitude which can occur between contacting surfaces of two immobile and fixed object[11]. In presence of body fluids, fretting can be accompanied by corrosive effects. The presence of water within human tissues initiates a repassivation reaction, where the exposed metal surface forms an oxide and releases hydrogen ions. Negatively charged chloride ions migrate to balance these positively charged hydrogen ions, producing hydrochloric acid, which dissolves metal alloys. The resulting corrosion debris generated from the modular junction appears responsible for ALTR[11].

Looking further at instances of pseudotumor recurrence, a study by Kwon looked at 40 revisions after the presence of symptomatic ALTR diagnosed on metal artifact reduction sequence MRI with elevated metal ion levels[6]. These patients all had metal-on-polyethylene bearings on titanium alloy femoral stems so there was only one site of modularity at the head-neck junction. They used the Goldberg criteria to assess fretting and corrosion and found that three-quarters of the patients had Grade 3 tissue damage and metal debris at the femoral component's trunnion neck taper[6]. They were revised to a ceramic femoral head with a titanium adaptor sleeve over the femoral stem trunnion. In the patient that experienced recurrence, there was no linear

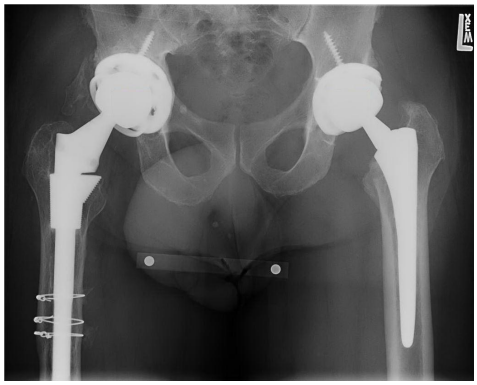

Figure 2 Initial post-operative anterior-posterior pelvic radiograph showing the components of the prosthesis well-aligned and well seated.

correlation to post-revision serum metal ion levels. Rather they suggested that pre-revision MRI findings of lesions with abductor deficiency and intra-operative tissue damage should be stronger predictive factors for post-revision complications such as pseudotumor recurrence[6].

Thus, it would lead us to believe that with an increase in the number of modular junctions, there exists an increased propensity for fretting corrosion and an increased incidence of ALTRs. Several recent studies looking at revision outcomes in THA with dual modularity suggest exactly this[5,8-11]. The benefits of dual modularity are clear, it provides greater flexibility and facilitates the adjustment of leg length, femoral anteversion, and offset in order to accurately reproduce the center of rotation of the hip. However, both axial and bending stresses at the stem-neck junction strongly influence fretting corrosion eventually leading to mechanical failure of the modular neck and the subsequent need for revision.

Kwon looked at outcomes after revision dual taper THA in about 200 patients with symptomatic ALTR due to taper corrosion[6]. A staggering 20% of the cohort experienced post-revision complications. 3% of those patients experienced pseudotumor recurrence. 5 of the patients were revised to a cemented monoblock femoral stem with a ceramic head, so recurrence may be less likely attributable to stem-neck modularity or head-neck taper corrosion. The authors attributed recurrence to surgical, patient, and implant factors. They hypothesized that incomplete surgical debridement and inadequate removal of pseudotumor can contribute. However, extensive debridement needs to be performed with preservation of nearby neurovascular structures.

The uniqueness of this case report is highlighted by the post-revision ALTR recurrence. Previously reported cases of stem-neck modularity leading to pseudotumor formation exhibited implant damage between two metal components[12]. This lends to the notion that micromotion between adjoining metal-on-metal components are susceptible to the same corrosion and metal ion deposition seen in MoM arthroplasty. In order for this mechanism to be true however, one would expect more cases of pseudotumor formation given the number of THAs performed yearly using stem-neck modularity.

Current recommendations in symptomatic patients with ALTRs suggest avoiding overreliance on any single investigative tool in the clinical decision-making process for revision surgery[13]. There should be a low threshold for clinical evaluation, especially in patients dual modularity THA. A combination approach has been recommended by the consensus statement between the American Association of Hip and Knee Surgeons, American Academy of Orthopaedic Surgeons, and Hip Society in regards to managing symptomatic patients with dual modular THA. The recommendation states "And in patients where revision in indicated, knowledge of the pre-revision risk factors we talked about earlier can mitigate the incidence of complications and need for re-revision."

CONCLUSION

This case highlights a post-revision pseudotumor recurrence in a modular femoral stem THA not utilizing metal-on-metal prostheses. This article aims to elucidate patient, surgical, and implant factors that may contribute to pseudotumor recurrence with a discussion of diagnostics, management, and prognosis.

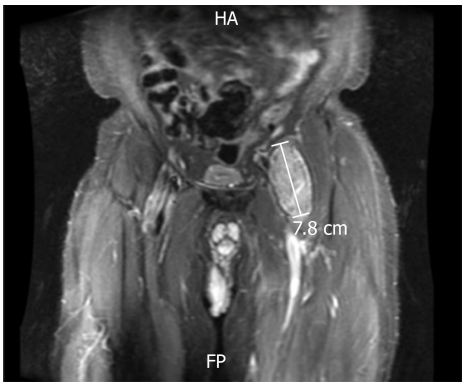

Figure 3 Pre-revision T2-weighted coronal magnetic resonance image showing a well-defined 7.8 cm complex lesion anterior to the left hip prosthesis.

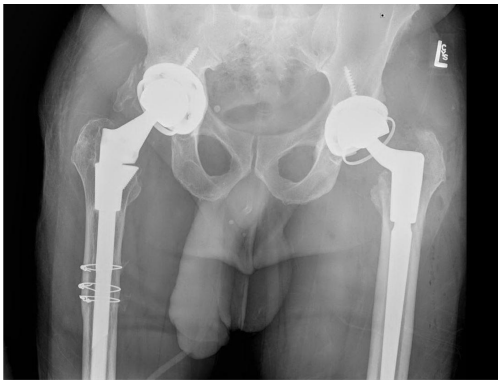

Figure 4 Post-revision anterior-posterior hip radiograph showing an aligned and well-fixed left hip prosthesis.

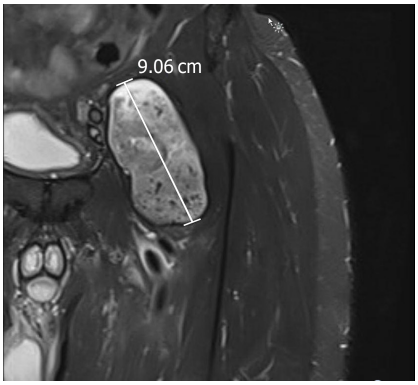

Figure 5 Post-revision short-T1 inversion recovery coronal magnetic resonance image demonstrating pseudotumor recurrence.

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CASE REPORT

Rupture of the long head of the biceps brachii tendon near the musculotendinous junction in a young patient: A case report

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Abstract

We report an unusual case of the long head of the biceps brachii tendon rupture near the musculotendinous junction in a young patient. The injury occurred in a young athlete during sports competition. The clinical presentation, surgical treatment, and technique with tenodesis using a unicortical button of the ruptured tendon were presented. The post-surgical recovery was uneventful, and the patient returned to sports in 6 mo. The treatment approach and surgical technique of the long head of biceps brachii rupture was reviewed and discussed. In conclusion, surgical treatment of the long head of the biceps brachii tendon rupture with unicortical button tenodesis resulted in a favorable outcome in a young athlete.

Key words: Athlete; Sport injury; Shoulder; Biceps tendon; Tenodesis

Core tip: We report an unusual case of rupture of the long head of the biceps brachii tendon near the musculotendinous junction in a young atheletc patient. The clinical presentation, surgical treatment, and technique with tenodesis using a unicortical button of the ruptured tendon were presented. The treatment approach and surgical technique of the long head of biceps brachii rupture was reviewed and discussed.

Citation: Liu X, Tan AHC. Rupture of the long head of the biceps brachii tendon near the musculotendinous junction in a young patient: A case report. *World J Orthop* 2020; 11(2): 123-128

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INTRODUCTION

Most of the biceps tendon pathologies occur secondary to degeneration and attrition of the rotator cuff[1]. Isolated injury to the long head at the biceps tendon near the musculotendinous junction is uncommon in young patients and it may be associated with overhead sports, weightlifting, or motions that require forceful supination, where an isolated biceps ruptures due to sudden stress[2]. Based on an epidemiological study in the United States, it is uncommon (1.1%) to perform isolated biceps tenodesis in young patients (age < 30 years) and most biceps surgeries were performed in patients with associated diagnoses related to rotator cuff or labral pathologies[3].

Ruptures of the long head of the biceps brachii tendon generally occur in a background of tendon degeneration and are often associated with subscapularis tears, superior labral anterior-posterior lesions or osteophytes[4]. Isolated ruptures are less common and occur more frequently in middle-aged patients[4,5]. They almost always occur near the tendon origin or at the proximal intertubercular groove[4,5]. Tears near the musculotendinous junctions are even rarer. We reported a case of an isolated rupture of the long head of the biceps tendon at the musculotendinous junction in a healthy 22-year-old man. The clinical course, operative management, and post-surgery recovery are presented.

In this case report, we are presenting a young athlete with biceps tear at musculotendinous junction. We used a unicortical biceps tenodesis button instead of the more commonly used bicortical button. The clinical outcome showed that the patient was able to return to professional competition and was satisfied with the outcome. This report provided information on the successful management of patient with high performance demand with a novel technique of using unicortical biceps tenodesis button and a brief literature review of the current practice of the management of biceps tear.

CASE PRESENTATION

Chief complaints

A 22-year-old, right hand-dominant male presented with a chief complaint of swelling, weakness and pain of the right arm following a softball injury.

History of present illness

The patient is a professional softball player. His injury occurred 2 wk before the consultation during a softball competition. He felt a pop sound over the right arm and a snapping sensation when pitching a ball and thereafter, had pain and a noticeable lump over the right anterior arm. The patient did not have prior shoulder or elbow symptoms.

History of past illness

The patient did not have any significant past illness.

Personal and family history

The patient did not have any significant personal or family illness.

Physical examination upon admission

On physical examination, a bulge was seen in the anterior aspect of the right mid-arm that became more pronounced with active flexion of the right supinated forearm, commonly known as "Popeye's sign" (Figure 1). There was tenderness around the bulge. During resisted elbow flexion, tension was palpable at the biceps tendon insertion but lost over the origin. There was reduced strength of forearm supination and elbow flexion compared to the contralateral side.

Laboratory examinations

The laboratory examination was used for pre-operation evaluation only and included full blood cells counts and renal panel, which are all within normal ranges.

Imaging examinations

Radiographic examination of the right upper limb did not show any significant soft-tissue or bony abnormalities. Magnetic resonance imaging (MRI) of the right arm revealed a complete rupture of the long head of biceps tendon in the proximal arm near the musculotendinous junction. The proximal portion of the long head of biceps muscle appeared retracted with prominent surrounding fluid/hematoma (Figure 2). This yielded a tendon gap of 6.0 cm. No pathology was identified in the shoulder joint or other parts of the arm.

Figure 1 Clinical photos of patient demonstrating the bulge at the right arm, "Popeye's sign".

FINAL DIAGNOSIS

An isolated rupture of the long head of the biceps tendon.

TREATMENT

The patient is a professional athlete and intended to continue his sports career. The treatment options were discussed with the patient and he wanted to maximize shoulder performance and reduce deformity. Surgical treatment was chosen and scheduled one month after the injury. A biceps tenodesis using a unicortical button was performed.

The patient was placed in the beach chair position under general anesthesia. A subpectoral approach with mini-open incision was used. A 3-cm longitudinal incision was made in the anteromedial aspect of the proximal humerus, beginning 1cm proximal to the inferior border of pectoralis major tendon. The dissection was carried on and aimed toward the humerus, avoiding the neurovascular structures over the medial aspect. The biceps which is deep to the pectoralis major tendon was then accessed. During exploration, the short head of the biceps was intact. The long head of the biceps was completely ruptured near the proximal musculotendinous junction.

The musculotendinous stump was then delivered through the wound and a nonabsorbable suture was placed through the remnant tendon, fascia and muscle belly using a whipstitch.

A unicortical metal button (BicepsButton™, Arthrex, FL, United States) was used for fixation of the ruptured biceps tendon. A 3.0-mm pin was drilled into the anterior cortex of humerus deep to the inferior border of the pectoralis major tendon. One end of the suture was passed through a hole in the button and then back through the opposite hole. The other end of the sutures was then passed through in the opposite direction. The button was loaded to an inserter and inserted through the pre-drilled 3.0-mm hole. The button was released in the intramedullary canal and retrograde traction was applied to the sutures to toggle the button against the inner anterior cortex. Tension-slip technique was utilized with controlled tension to the two ends of sutures to tighten the button and appose the biceps tendon to the anterior cortex firmly. A free needle attached to one end of the suture was then passed through the biceps, and the two ends were tied to complete the tenodesis. The post-operative radiographs are shown in Figure 3.

OUTCOME AND FOLLOWUP

Post-operatively, the right arm was placed in a sling at 90 degrees of flexion and followed with passive range of motion exercise in the first four weeks. The patient started gradual active range of motion excise and strengthening from the 5th post-operative week. He regained pre-morbid functional performance and returned to sports 6 months after the surgery and was satisfied with arm strength and cosmetic appearance after surgical treatment.

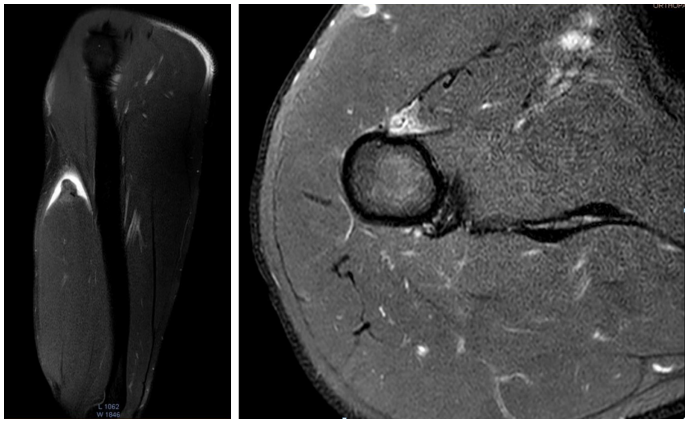

Figure 2 Sagittal and axial images of magnetic resonance imaging showing the proximal portion of the long head of biceps muscle appeared retracted with prominent surrounding fluid/hematoma.

DISCUSSION

The biceps brachii muscle functions as a forearm supinator and elbow flexor[1]. The biceps brachii muscle is composed of a short and long head that have different proximal origins on the scapula but share a common distal insertion[1]. The biceps is an important muscle during pitching biomechanics and predominantly activates during cocking to accomplish elbow flexion and then reactivates during follow-through to decelerate the forearm[6]. Rojas *et al*[7] performed an biomechanics analysis and found that Its activity is higher during windmill pitch than during overhead throw, especially before and after ball release between 9 o'clock and the follow-through phase.

The epidemiology of the pathology varies from degenerative changes in the elderly to traumatic injuries related to weightlifting or throwing in younger patients[8]. The biceps tendon pathologies usually occur due to degeneration of the rotator cuff middle-aged to older patients[1]. Isolated injury to the biceps tendon is uncommon in young patients and it may be associated with overhead sports, weightlifting, or motions that require excessive supination, where a sudden stress may result in an isolated bicep rupture without pre-existing glenohumeral pathology[2]. Barrentine *et al*[9] reported that forceful overloading of the biceps in throwing athletes, especially baseball pitchers, can result in traction and avulsion of the biceps in the deceleration phase of throwing.

A biceps tendon rupture often associated with a popping sound after traumatic injury. Clinical presentation may include localized sharp pain, ecchymosis and swelling. As shown in Figure 1, a biceps tendon rupture is classically presented with Popeye's sign, a visible muscle prominence in the mid arm. Radiographic investigation includes magnetic resonance imaging or ultrasound to delineate a complete or partial rupture and investigate associated shoulder pathologies.

Based on an epidemiological study in the United States, it is uncommon (1.1%) to perform isolated biceps tenodesis in young patients (age < 30 years) and most biceps surgeries were performed in patients with associated diagnoses related to rotator cuff or labral pathologies[3]. After rupture of the long head, there may be loss of up to 20% of muscle strength[10]. Surgical treatment of the rupture of the biceps in young or active sportsmen is recommended, which is able to restore both flexion and supination strength and reduce the risk of cosmetic deformity[10].

The treatment of biceps tendon ruptures shoulder be tailored to patients. Factors need to consider include: Age of the patients and their demand, the quality of the tendon to be tenodesed and the position where tenodesis is possible *etc*.

The patient presented here is a young throwing athlete who places a high demand on his upper limb and who had concerns regarding the cosmetic appearance of the Popeye arm. Surgical treatment with biceps tenodesis was therefore chosen over conservative management.

The ideal location of tenodesis and method of fixation is debated[1-3,5,11]. Tenodesis of the long head of the biceps can be done proximally (suprapectoral) or distally (subpectoral). The proximal fixation site is either within the glenohumeral joint to the intact rotator cuff or just proximal to or within the bicipital groove, and the fixation is typically carried out arthroscopically. Subpectoral biceps tenodesis has emerged as a new technique to treat biceps ruptures. Initially described by Mazzocca *et al*[12,13], subpectoral biceps tenodesis secures the biceps tendon distal to the bicipital groove

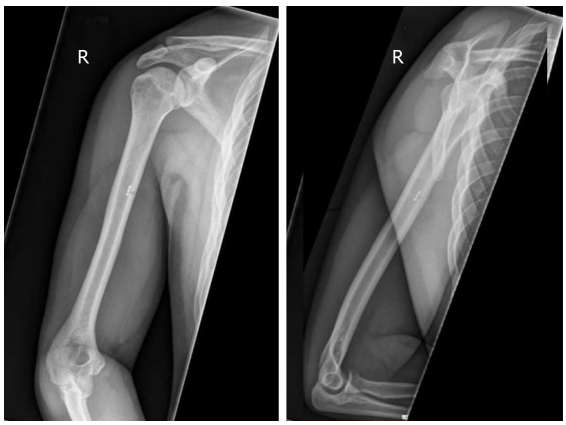

Figure 3 The post-operative radiographs in anterior-posterior view and lateral view show the unicortical button was placed in the anterior cortex of humeral shaft.

through a mini-open incision. There are a few proposed advantages of subpectoral tenodesis[11]. Firstly, the relevant anatomy is can be easily oriented and identified, which aids the consistency of the length-tension relationship. Secondly, as the fixation occurs distally to the bicipital groove, it reduces of risk of pain at this site. Thirdly, subpectoral biceps tenodesis has the versatility of using interference screw and suture anchor fixation with their attendant biomechanical advantages.

The rupture occurred near the proximal musculotendinous junction. There was inadequate tendon length for suprapectoral tenodesis, and it would be technically challenging to achieve a proper length-tension relationship. Apart from its purported advantages as mentioned above, subpectoral tenodesis was chosen based on these considerations. A shoulder arthroscopy was not performed in this case. The patient's profile, history and clinical examination suggested it was an isolated biceps tendon lesion and the MRI performed confirmed this finding. The complication of leaving the proximal stump in situ is unclear and to the authors' knowledge, not reported in literature. As additional proximal incision and dissection would be required to retrieve the proximal stump, it was not performed.

In this case, we used a unicortical biceps tenodesis button instead of the more commonly used bicortical button. The benefits of using unicortical button comparing to bicortical or interference screw are reduced risk of iatrogenic brachial plexus injury and humeral fracture[14,15] as only one cortex is drilled under direct visual with a cortical defect of 3-mm which minimizes the risk of humerus fracture[16]. In a biomechanical cadaveric study comparing the unicortical button with interference screw fixation, considerably less displacement in cyclic loading in the unicortical button group was demonstrated with equivalent ultimate load to failure and stiffness[17].

CONCLUSION

Isolated rupture of the long head of the biceps brachii tendon near the musculotendinous junction is an uncommon injury. In young and active patients, surgery is the preferred treatment choice to restore elbow flexion and forearm supination strength and should be recommended. A unicortical button is effective in achieving a stable repair with favorable surgical outcome.

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CASE REPORT

Cleft foot: A case report and review of literature

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Author contributions: Leonchuk SS and Blanchard AJ reviewed the literature; Leonchuk SS, Blanchard AJ and Neretin AS contributed to manuscript drafting; Leonchuk SS revised the manuscript for important intellectual content; Neretin AS was the patient's surgeon; all authors issued final approval for the version to be submitted.

Informed consent statement: The patient has provided informed consent for the case report to be published. Informed consent was obtained from all individual participants included in the study.

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Abstract

BACKGROUND

Cleft foot is a very rare congenital anomaly, which is characterized by central rays deficiency of the foot. It is also known as split foot or ectrodactyly of the foot, and it is very often combined with splitting of the hands. The defect develops due to insufficient activity of the median apical ectodermal ridge, which leads to an increase in cell death or a decrease in cell proliferation. Due to the rarity of the pathology, there are few papers on the surgical treatment of this congenital foot disease, and publications to date concern the treatment of children.

CASE SUMMARY

We present a clinical case of congenital splitting of the feet and hands in a 31-year-old woman and a long-term result of foot treatment using the minimal arrangement of the Ilizarov apparatus. The patient had paternal inheritance of the trait. After the surgical treatment, cosmetic view and functional condition of the foot were improved and persisted two years after intervention. There were no complications in the treatment process.

CONCLUSION

The possibility of dosed control and stable fixation of the foot rays made it possible to create favorable conditions for the healing of the central wound and the closure of the segment splitting without complications. The long-term outcome of the treatment of foot congenital splitting using the proposed Ilizarov apparatus arrangement has shown its effectiveness. Our approach should be considered as an option of treatment in similar cases.

Key words: Cleft foot; Split foot; Ectrodactyly; Congenital malformation; Ilizarov; Case report

Core tip: We present a clinical case of rare congenital anomaly of feet and hands in a 31-

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year-old woman and a long-term result of foot treatment using the minimalist construct of the Ilizarov external fixator. The treatment approach made it possible to create favorable conditions for healing of the central wound and closure of segment splitting without complications. The long-term outcome of our treatment of the congenital foot anomaly has shown its effectiveness and can be considered in similar cases.

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INTRODUCTION

Cleft foot is a very rare congenital anomaly, which is characterized by central rays deficiency of the foot: From shortening of the central toe to the absence of several rays of the foot. It is also known as split foot or ectrodactyly of foot, and it is very often combined with splitting of the hands. The first report of this anomaly was from South Africa in 1770[1]. The prevalence of the disease is 1 case per 90000 newborns and 1 case per 120000 in the population[2,3], and according to some data, 1 case per 1000000 live newborns[4]. It may be isolated or may be a part of a syndrome of deformity, and it is more common as bilateral[5]. The defect develops due to insufficient activity of the median apical ectodermal ridge, which leads to an increase in cell death or a decrease in cell proliferation[6]. Cleft foot (or hand) is usually inherited as an autosomal dominant type with reduced penetrance, although there are reports of sporadic, autosomal recessive and X-related forms[7,8]. To the present date, seven types of this anomaly have been described. Chromosomal rearrangement leads to the association of ectrodactyly with other disorders. Today, there are more than 50 syndromes that are associated with congenital splitting of the feet/hands. There are possible combinations of this malformation with anencephaly, cleft lip and palate, clinodactyly, scoliosis, nonperforation of the anus, anonychia, cataract and deafness[9].

Surgical reconstruction in splitting of the hands includes the closure of the cleft, the release of syndactyly, correction of the adduction of the first finger and the removal of transverse or deformed bones[9,10]. Surgical treatment of ectrodactyly of the feet is discussed to date[11]. Due to the rarity of the pathology, there are few publications about surgical treatment of this congenital foot disease; moreover, available literature concerns the treatment of children[12-18]. We present a clinical case of congenital splitting of the feet and hands in an adult patient and a long-term result of applying the minimum arrangement of the Ilizarov apparatus to correct this foot defect.

CASE PRESENTATION

Chief complaints

A female patient, 31-years-old, was admitted to the Ilizarov Center with complaints of painful calluses on the feet, difficulty in selecting shoes, a pronounced limitation of the function of the hands and a cosmetic defect of the lower (Figure 1) and upper extremities (Figure 2).

History of present illness

The patient is a resident of the countryside. There are no demographic and origin features. From the anamnesis, it is noted that her grandfather, father, brother and paternal uncles also have a similar anomaly in the development of hands and feet. Her aunt and grandmother have no such problems.

History of past illness

The patient had not been treated surgically; she was denied medical care and offered only amputation of the fingers at other facilities.

Physical examination

The patient wore overly wide shoes. The range of motion in elbow, wrist, hip, knee and ankle joints was full. The feet were strongly spread and represented by two rays (deep cleft with absence of central foot rays) (Figure 1). The patient had pronounced

Figure 1 Photo and x-ray pictures of patient's feet before treatment. A: Cleft feet; B: X-rays of feet in anterior-posterior and lateral view (absence of central feet rays).

limitation of function and severe cosmetic defect of hands (each segment was represented by three rays with absence of fingers 1-4) (Figure 2). She could hold large non-heavy things, and her palm-finger grasp was preserved.

Figure 2 Photo and x-ray pictures of patient's hands. A: Split hands with absence of fingers 1-4; B: Three metacarpals with transverse bone in base of cleft and absence of fingers 1-4.

Laboratory examination

Blood analysis and urine analysis were normal. Electrocardiogram, chest x-ray and arterial blood gas were also normal.

Imaging examination

The feet were represented by two rays (V type according to Blauth W. and Borisch N.C. classification[2], II type according to Abraham E *et al*[18]) (Figure 1). The hands were represented by three metacarpals with transverse bone in base of cleft and absence of fingers 1-4 (Figure 2).

FINAL DIAGNOSIS

Congenital anomaly, ectrodactyly of the feet (V type according to Blauth W. and Borisch N.C. classification, II type according to Abraham E *et al*[18]) and ectrodactyly of the hands.

TREATMENT

Surgical treatment was divided into several stages. To start surgical treatment from the feet was the patient's desire because the anomaly of the feet caused her more inconvenience. At the first stage, we performed surgical treatment on the left foot using a small arrangement of the Ilizarov apparatus (Figure 3). The patient noted more discomfort with the left foot than with the right foot.

First, open access was performed on the left foot, rudiment of central foot ray was removed and resectional wedge-shaped osteotomy of cuboid and cuneiform bones was performed to bring the rays together (Figure 3A). In the midfoot area, two olivial wires were pushed towards each other. Through the metatarsal bones, two olivial wires were also passed towards each other. Each pair of olivial wires was fixed in the semi-ring of the original Ilizarov apparatus. The supports were interconnected by straight rods. Then corrective osteotomy of both metatarsal bones was performed (Figure 3A) with fixation of each ray by two wires, which were fixed on the rods. Correction of the foot rays position was made by tensioning the wires in the supports (Figure 3B). After that, we performed suturing of the central space and Z-shaped skin

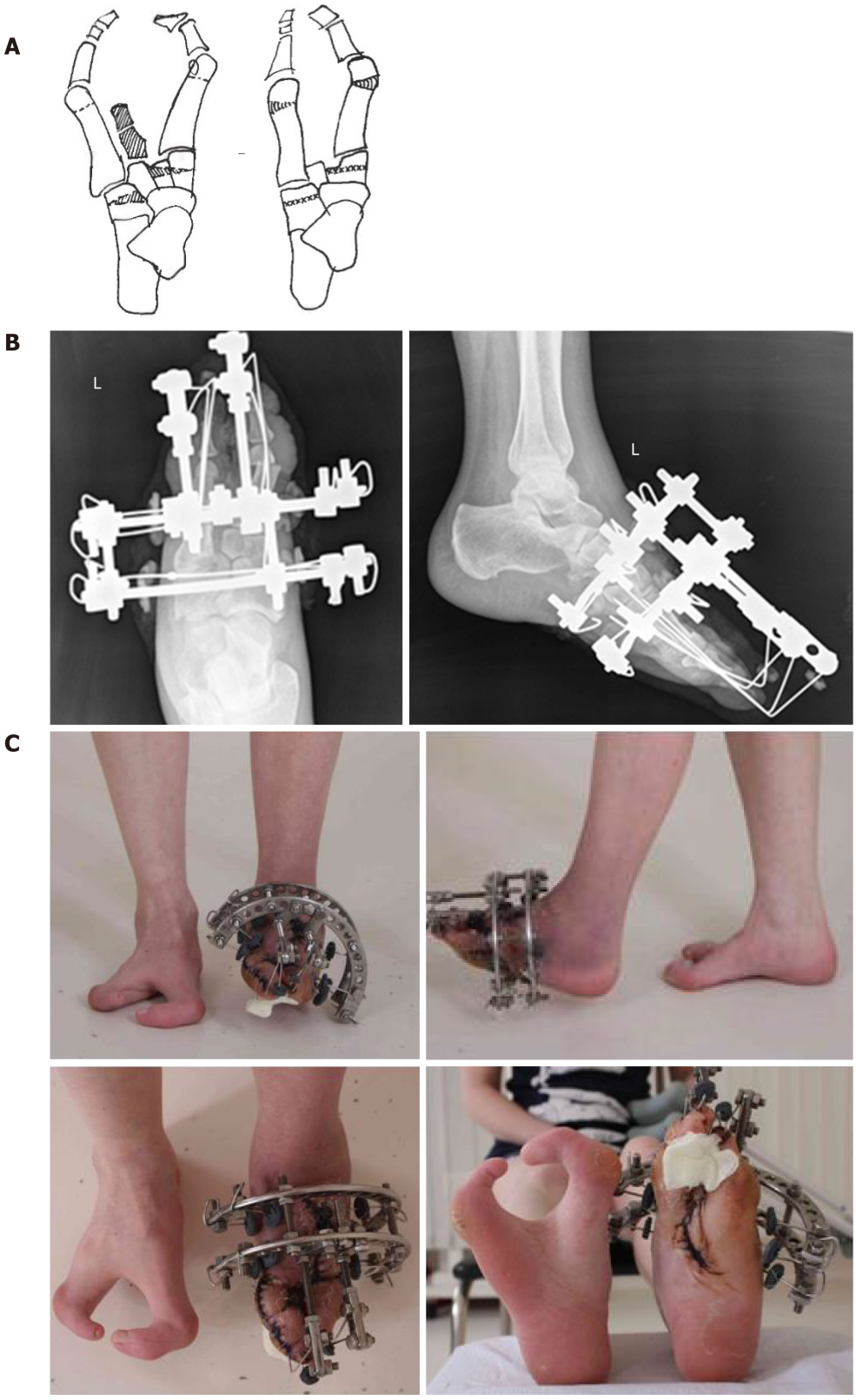

Figure 3 Scheme of surgical intervention, x-rays of left foot and photo of feet during treatment process. A: The first step was resectional wedge-shaped osteotomy of cuboid and cuneiform bones with removing of rudiment of central foot ray. The second step was corrective osteotomy of both metatarsal bones; B: Correction and fixation of foot rays by minimalist construct of Ilizarov apparatus; C: Closure of foot splitting.

plasty to close the foot defect. Patient started walking by gradually increasing weight-bearing on the left foot beginning on the 3rd d after surgery. Dressings after surgery were performed daily for 3 d and then weekly. The patient was discharged for outpatient treatment at the place of residence after 2 wk. The period of fixation of the left foot by the Ilizarov apparatus was 59 d.

OUTCOME AND FOLLOW-UP

The treatment approach made it possible to create favorable conditions for healing of the central wound and closure of segment splitting without complications. Two years after surgery, the result of the treatment on the left foot was maintained, and the patient was satisfied. According to the patient, the support on the foot improved (Figure 4). For family reasons, the patient was forced to take a long pause between the stages of treatment of the feet. Currently, we plan to perform a similar surgical treatment on the right foot.

DISCUSSION

Cleft hand/foot deformity is a rare congenital anomaly. Severity of hand/foot splitting varies[5]. Prenatal diagnosis of cleft hand/foot malformations can be established from the first trimester[5,19]. A number of publications devoted to this disease describe only pathogenesis and diagnostics of this pathology[3-5,7,8,19].

Surgical treatment strategies of this disorder are debatable. Due to the rarity of the pathology, there are few publications on the surgical treatment of ectrodactyly of the foot, and all of them describe the experience of children's treatment[12-18]. There are no publications about surgical treatment of adults with this congenital malformation of feet. Some authors recommend that children do not undergo surgery if the feet are well-supporting and it is possible to wear normal shoes[11]. Other colleagues insist that the surgical treatment of this splitting should be carried out before the age of 1 year[12,13]. The aim of treatment of patients with this congenital anomaly is to improve foot function and cosmetic view[14]. In children, operative treatment is aimed at closing the central foot defect with possible osteotomy/resection of the segment bones and fixation of the forefoot by wires or screws and even transplanting fingers into the defect zone[12-17,20] or amputation[18] (Table 1).

However, the adult's foot is more rigid than a child's segment, and it is difficult for such patients to use regular shoes or an orthosis. Often, patients with abnormal development of the distal lower extremities have impaired segment function and gait.

Surgical reconstruction in splitting of hands includes the closure of the cleft, the release of syndactyly, correction of the adduction of the first finger and the removal of transverse or deformed bones[9,10]. The Snow-Littler and Miura procedures are the most common surgical techniques to close the cleft of hand and widen the thumb-index finger web space[21,22].

According to the surgical scheme (classification) of Abraham E *et al*[18], the recommended treatment of I type split foot (deficiency of the second or third ray to the metatarsal area) is to create syndactyly between the existing rays and partial correction of valgus deformity of the first ray if necessary. In type II (deep cleft to the tarsal part with the extension of the forefoot), syndactyly with osteotomy of the first ray is shown. With type III, when completely missing from the first to the third or fourth ray, the operation is not required. The authors recommend performing an amputation of the first foot ray after reaching the age of 5 years.

There are a number of publications in the literature on the use of external fixation to create favorable conditions for the healing of central wounds/defects of the soft tissues of the forefoot in the setting of diabetes and vascular disorders. Strauss *et al*[23] described the successful use of an external mini-fixator in the forefoot with the central wound of forefoot in the presence of diabetes and peripheral vascular diseases. Oznur *et al*[24] showed a positive result in the treatment of a defect in the forefoot after resection in the presence of diabetes using the Ilizarov apparatus. In our case of foot congenital splitting in an adult patient, we applied the minimal arrangement of the Ilizarov apparatus to create favorable conditions for healing the wound without tension and with stable fixation of the achieved result, which was described for the first time.

CONCLUSION

The possibility of dosed control and stable fixation of the foot rays made it possible to create favorable conditions for the healing of the central wound and the closure of the segment splitting without complications. The long-term outcome of the treatment of foot congenital splitting using the proposed Ilizarov apparatus arrangement has shown its effectiveness. Our approach should be considered as an option of treatment in similar cases.

Table 1 Surgical interventions in patients with cleft foot according to different authors

Authors	Number of patients/feet	Surgery, technique	Results
Sumiya *et al*[12]	8/16	Reconstruction of five toes: Closing of defect; creation of third toe by double pedicle flaps from the cleft area; separating third and fourth toes to create five toes by using free skin grafts from the skin defects	Excellent results in terms of both the function and the aesthetics
Wood *et al*[13]	9/15	Triangular flaps, in addition metatarsal osteotomies, intermetatarsal ligament reconstruction, fixation by Kirschner wires	The feet maintained good cosmetic and function
Choudry *et al*[14]	3/5	Removal of central wedge of skin; excision of central metatarsal; lateral release of the adductors and capsule of hallux metatarsophalangeal joint; osteotomy of fifth metatarsal; fixation by Kirschner wire; soft tissue syndactylization	All patients were happy with the cosmetic results
Tani *et al*[15]	21/32	Simple closure, silicone block insertion, application of a double-pedicled flap	Only 1 patient of 14 with long-term follow-up complained of pain following walking
Talusan *et al*[16]	1/2	Suture-button construct	Positive result
Lejman *et al*[17]	3/5	Wedge resection of the metatarsals with screw fixation and skin syndactyly	All patients were satisfied
Abraham *et al*[18]	16/32	Soft-tissue syndactylism, partial hallux valgus correction; soft-tissue syndactylism with first-ray osteotomy; first-ray amputation	23 of the 24 procedures performed gave a satisfactory result
Sunagawa *et al*[20]	1/1	Microvascular toe transfer from a contralateral side that was amputated	Longitudinal growth of the grafted toe was symmetric, compared to the recipient toes, and the appearance of the treated foot was quite natural

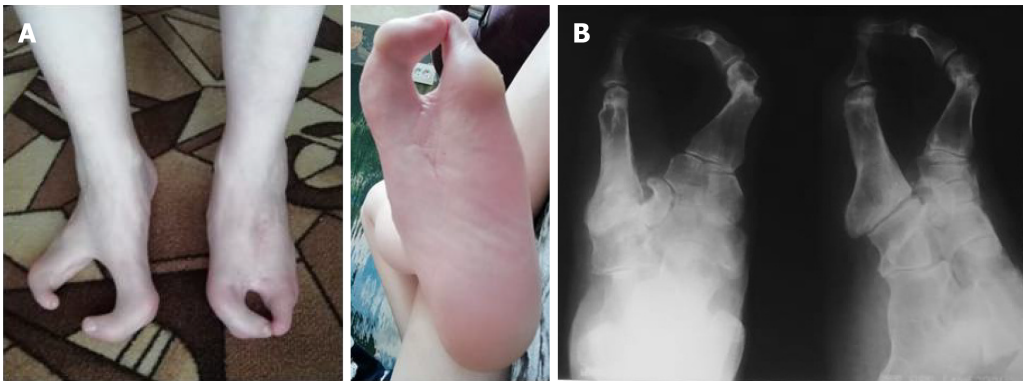

Figure 4 Photo of feet and x-ray pictures of patient's left foot after 2 years after surgical intervention. A: Closure of foot splitting; B: X-rays of left foot in anterior-posterior and axial view.

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CASE REPORT

Minimally invasive tenodesis for peroneus longus tendon rupture: A case report and review of literature

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Abstract

BACKGROUND

Peroneal tendon disorders are common causes of lateral hindfoot pain. However, total rupture of the peroneal longus tendon is rare. Surgical treatment for this condition is usually a side-to-side tenodesis of the peroneal longus tendon to the peroneal brevis tendon. While the traditional procedure involves a long lateral curved incision, this approach is associated with damage to the lateral soft tissues (up to 24% incidence).

CASE SUMMARY

A 50-year-old female had developed pain at the lateral aspect of the hindfoot 1 mo after an ankle sprain while walking in the street. Previous treatments were anti-inflammatory drugs, ice, rest and Cam-walker boot. At physical exam, there was pain and swelling over the course of the peroneal tendons. Ankle instability and cavovarus foot deformity were ruled out. Eversion strength was weak (4/5). Imaging showed complete rupture of the peroneal longus tendon associated with a sharp hypertrophic peroneal tubercle. Surgical repair was indicated after failure of conservative treatment (physiotherapy, rest, analgesics, and ankle stabilizer). A less invasive approach was performed for peroneal longus tendon debridement and side-to-side tenodesis to the adjacent peroneal brevis tendon, with successful clinical and functional outcomes.

CONCLUSION

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Peroneus longus tendon tenodesis can be performed through a less invasive approach with preservation of the lateral soft tissue integrity.

Key words: Peroneus longus tendon; Complete rupture; Tenodesis; Minimally invasive surgery; Wound breakdown; Case report

Core tip: Traditionally, tenodesis of the peroneus longus tendon has been performed through a long lateral curved incision on the hindfoot. However, this approach is often associated with damage of the lateral soft tissues, having an incidence that ranges from 2.4% to 54%. The highlight of this study is its presentation of a less invasive approach for side-to-side tenodesis of full-thickness rupture of the peroneus longus tendon, which preserved most of the lateral soft tissue prone to wound breakdown.

Citation: Nishikawa DRC, Duarte FA, Saito GH, de Cesar Netto C, Fonseca FCP, Miranda BR, Monteiro AC, Prado MP. Minimally invasive tenodesis for peroneus longus tendon rupture: A case report and review of literature. *World J Orthop* 2020; 11(2): 137-144
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INTRODUCTION

Acute peroneus longus tendon (PLT) ruptures are uncommon[1-3]. They rarely occur as an isolated injury, being more often associated with peroneus brevis tendon (PBT) partial or complete tears[4-6]. In general, the etiology involves mechanical and anatomical predisposing factors. An acute injury is the result of a sudden inversion sprain of the ankle. The most common sites of PLT lesions are where the tendon is subjected to attrition with underlying bones, such as the tip of the lateral malleolus, the peroneal tubercle, or the os peroneus[7-9]. Cavovarus deformity and lateral tibiotalar instability can also subject the PLT tendon to additional frictional forces on these points[1,4,10-12]. The six current options of treatment are nonoperative procedures, peroneal tendoscopy, opened debridement and tubularization of the remaining tendon, side-to-side tenodesis, tendon transfer of the flexor hallucis longus or flexor digitorum longus, and reconstruction with allograft or autograft[13-18]. Side-to-side tenodesis is considered an effective procedure for the treatment of partial or complete ruptures of the PLT, with successful results allowing patients to return to their previous activities[19]. However, this procedure has traditionally been performed through a long lateral curved incision that carries the risk of such soft tissue damage as dehiscence of the surgical wound, sural nerve transection, swelling, and infection[13,14].

The aim of this report was to describe the case of a patient who underwent a side-to-side tenodesis of the PLT to the PBT for the treatment of a full-thickness rupture of the PLT tendon using a minimally invasive approach. The approach was shown to be a reasonable option to preserve soft tissue on the lateral site of the hindfoot and ankle most prone to wound breakdown.

CASE PRESENTATION

Chief complaints

A 50-year-old female that works in a public hospital as a nurse assistant presented with complaints of severe pain and swelling on the right hindfoot along the course of the peroneal tendons (PT) after an ankle sprain.

History of present illness

The patient presented to the outpatient clinic of our hospital to address pain and swelling at the lateral aspect of the right hindfoot that had lasted for 1 mo after an ankle sprain while walking along the street. Previous treatments elsewhere were based on anti-inflammatory drugs, ice, rest and on the use of a Cam-walker boot (CWB).

History of past illness
The patient reported only hypertension as a chronic comorbidity.

Physical examination
Pain on palpation and swelling were evident over the course of the PT. No clinical signs of ankle instability were observed under stress maneuvers (anterior drawer and talar tilt tests). A subtle bilateral and symmetrical cavovarus foot was noted. Weakness in eversion was present under resistance, with strength of 4/5.

Imaging examination
Foot and ankle plain radiographic series imaging and magnetic resonance imaging (MRI) of the ankle were performed. MRI T2-weighted images showed complete rupture of the PLT, surrounded by extensive synovitis (Figure 1). With plain radiographic images of the ankle anteroposterior view and the MRI T1- and T2-weighted images, it was possible to identify a sharp hypertrophic peroneal tubercle (Figure 2). An MRI exam of the leg was carried out to evaluate the status of the peroneal muscles and to determine if there was any evidence of fatty infiltration and/or muscle atrophy.

FINAL DIAGNOSIS
Full-thickness rupture of the PLT associated with a sharp hypertrophic peroneal tubercle.

TREATMENT
Surgical repair was indicated after 6 mo of failure of the conservative treatment (physiotherapy, rest, anti-inflammatory drugs, and ankle stabilizer to restrict inversion-eversion movements). Preoperatively, the visual analogue scale (VAS) for pain and the American Orthopedic Foot and Ankle Society (AOFAS) ankle-hindfoot scores were applied. The patient's VAS score was 9 and AOFAS ankle-hindfoot score was 39.

The surgical procedure was performed under regional anesthesia, with the patient placed in a lateral position using a well-padded nonsterile thigh tourniquet inflated to 300 mmHg. The minimally invasive approach consisted of two short incisions (Figure 3). Anatomical references were marked with a Codman skin marking pen and included lateral malleolus and base of the fifth metatarsal. Proximally, a longitudinal incision of approximately 3 cm in length was made at 1 cm posterior to the posterior border of the distal fibula and 1.5 cm above the tip of the lateral malleolus. The PT sheath was dissected and opened to expose the proximal portion of the PLT but the superior peroneal retinaculum remained intact (Figure 4). Care was taken to avoid the sural nerve and the lesser saphenous vein that runs laterally to the Achilles tendon[20,21]. Distally, a longitudinal incision of 3 cm in length was made parallel to the ground, going backwards from the tip of the base of the fifth metatarsal base. In the distal incision, the distal stump of the remaining PLT was dissected and released at the cuboid groove. Due to the presence of a hypertrophic peroneal tubercle, a short middle incision of 2 cm was made for its resection (Figure 3B). The PLT was then brought out of its sheath through the proximal incision, and its nonviable portion was resected (Figure 4A). After debridement of the PLT, the remaining proximal stump of the native PLT was sutured side-to-side to the PBT with two U-shaped lateral sutures using No. 1 Vicryl (Ethicon Inc, Johnson & Johnson, Bridgewater, NJ, United States) (Figure 4B). This suture was made above the superior peroneal retinaculum to prevent volume effect of increased pressure within the retromaleolar groove (Figure 5). Finally, the three incisions were closed in layers. In the proximal incision, the PT sheath was closed with No. 1 Vicryl, the subcutaneous tissue with No. 3 Monocryl (Ethicon Inc, Cornelia, GA, United States), and the skin with No. 4 nylon. In the middle and distal incisions, the subcutaneous tissue was closed with No. 3 Monocryl and the skin with No. 4 nylon. After closure of the surgical wounds, a sterile soft dressing and a splint were applied with the foot in the neutral position.

OUTCOMES AND FOLLOW-UP
The patient remained nonweight-bearing for 2 wk with the cast. After 2 wk, the sutures were removed and full weight-bearing was allowed as tolerated with a CWB.

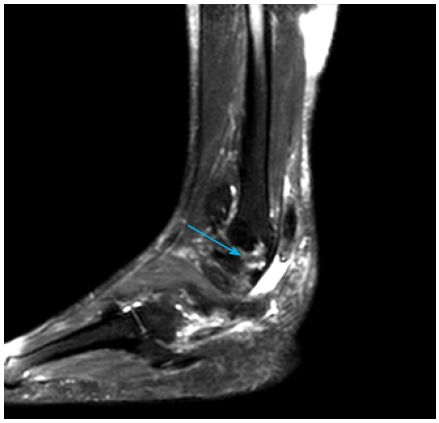

Figure 1 Preoperative ankle magnetic resonance imaging for diagnosis and evaluation of the type of peroneal tendon injuries. Ankle magnetic resonance imaging T2-weighted sagittal image showed complete rupture of the peroneus longus tendon (blue arrow).

Concerning evolution of the surrounding soft tissues and surgical wound, no complications of healing were noted. Sensitivity of the lateral skin of the hindfoot was preserved and similar to the contralateral foot. At that time, physical therapy was initiated, focusing on dorsiflexion/plantarflexion range of motion to prevent adhesions. Inversion/eversion movements were prohibited to prevent rupture of the suture of the tenodesis. The patient was instructed to always maintain the CWB, except for hygiene purposes and dorsiflexion/plantarflexion exercises. At 6 wk postoperative, the patient was out of the CWB with minimal swelling, and inversion/eversion movements were allowed; the patient was transitioned into an ankle stabilizing orthosis. From that point, the physical therapy program was oriented for inversion/eversion movements and to progressively restore proprioception and strength. The ankle stabilizing orthosis was used progressively less, according to the patient's rehabilitation.

At 12 wk of follow-up, physical examination revealed that there was no pain on palpation or restriction of inversion. Surgical incisions were fully healed, and swelling had decreased significantly (Figure 6). The patient presented VAS score of 0 and AOFAS ankle-hindfoot score of 90. At 6 mo of follow-up, the patient finished physiotherapy and returned to her prior level of activities. In physical examination, there was still no pain and peroneal strength was 5/5. The VAS score was 0 and AOFAS ankle-hindfoot score was 98. At 14 mo of follow-up, the patient reported that she was feeling great, with no complaints, and was fully active.

DISCUSSION

Treatment of complete rupture of the PLT is based on patient symptoms, such as pain, loss of function, or instability. Inactive and asymptomatic patients can be treated conservatively. However, in cases of active and symptomatic patients, the outcomes of nonsurgical management are poor, with the need of surgical treatment to provide pain relief and to support return to prior level of activities[5,22-26]. Tenodesis of the proximal stump of the ruptured PLT to the intact PBT has been described and widely used for this type of injury, with satisfactory clinical and functional outcomes[1,27]. However, this procedure has traditionally been performed through a long lateral curved incision from the lateral retromaleolar area to the base of the fifth metatarsal[11,28]. This longer lateral approach is often associated with damage to the lateral soft tissues, resulting in scar tenderness, sural nerve lesion, wound dehiscence, swelling, adhesive tendinitis, subluxation of the PT, and infection.

These complications are reported in the literature in an incidence that ranges from 2.4% to 54%[13,14,23,29]. In a study involving 30 patients treated for PT tears through the same long lateral approach, Steel *et al*[29] showed that 58% of the patients had scar tenderness, 54% presented lateral ankle swelling, 27% had numbness over the lateral surface of the ankle, and 31% had pain at rest. Likewise, Redfern *et al*[23] reported postoperative complications in 31% (9/28) of patients treated for concomitant tears of PBT and PLT through the same long lateral incision. Three developed superficial wound infections, one wound dehiscence, two sural neuritis, one complex regional pain syndrome, and one adhesive tendinitis. Here, we have presented the case of a symptomatic patient with a full-thickness rupture of the PLT that was successfully

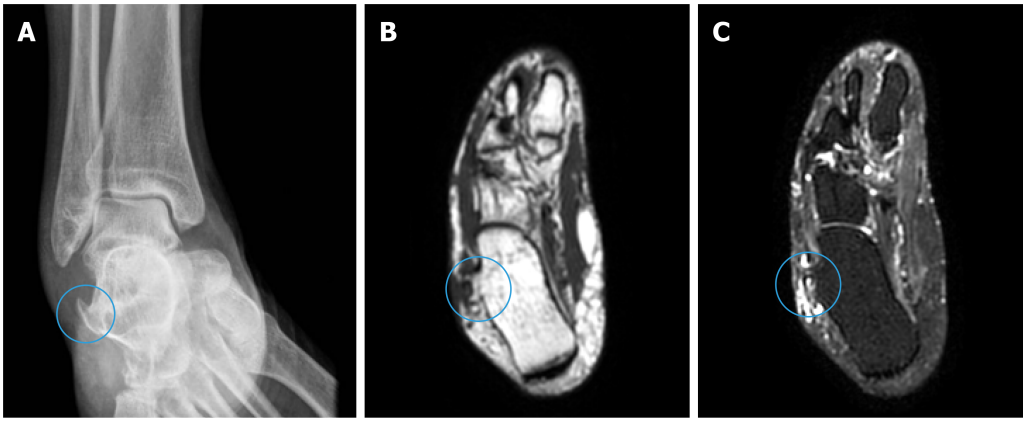

Figure 2 Preoperative plain radiograph and magnetic resonance imaging evaluation for surgical planning. A: Ankle plain radiograph anteroposterior view showing a sharp hypertrophic peroneal tubercle (blue circle); B and C: Ankle magnetic resonance imaging T1- and T2-weighted axial images (B and C respectively) demonstrated the hypertrophic peroneal tubercle with underlying bone edema (blue circles).

treated with side-to-side tenodesis of the PLT to the PBT, without any soft tissue compromise in the postoperative follow-up. To our knowledge, this is the first study to describe a less invasive approach for the PLT tenodesis procedure.

The main advantage of our technique was that it allowed for performance of tenodesis of the PLT to PBT through two separate short incisions, with less aggression to the surrounding soft tissue. We were able to keep the integrity of deep structures, such as the superior peroneal retinaculum, giving us confidence to orient early mobilization of the ankle and avoiding additional scar tissue that may restrict the tenodesis suture gliding or postoperative luxation of the peroneal tendon. Consequently, all this care with the soft tissue integrity provided less pain in the postoperative period, faster healing of the wound, and faster recovery. The indication of our technique can be extended to the group of patients at higher risk of wound complications, such as diabetics, smokers, and vasculopaths.

Both incisions were designed to be easily complemented with other incisions in case a patient requires additional procedures, such as lateral ligament reconstruction, calcaneal osteotomy for varus realignment, or hypertrophic peroneal tubercle (HPT) resection. Our proximal approach does not interfere in the curved incision along the anteroinferior margin of the fibula for the Brostrom-Gould reconstruction, the lateral oblique incision at the hindfoot for calcaneal osteotomy, and an additional short incision, which can be performed for resection of the HPT. In this particular case, the authors decided on HPT removal because it was much more prominent than the usual images from overall patients and it presented with bone edema beneath (in MRI, indicating friction between the HPT itself and the PT). In fact, we believe that this was the etiologic factor since lateral ligaments were still present in the MRI images and at physical exam the patient did not present a significant cavovarus foot. An enlarged peroneal tubercle interferes with the normal gliding of the PLT[6,15,30]. Literature has advised for excision of HPT since it may predispose tenosynovitis and recurrent tears of the PT[15].

CONCLUSION

In conclusion, the minimally invasive approach described herein should be considered for surgical treatment of PLT, such as tenodesis. It represents a simple and effective alternative to the long lateral curved incision. With two short incisions, it preserves soft tissue integrity above the PT course. Besides that, it can be useful for those patients at higher risk of wound breakdown. Further studies analyzing clinical and functional outcomes in a larger population and with longer follow-up are needed to determine the precise roles of this technique in treatment of PLT.

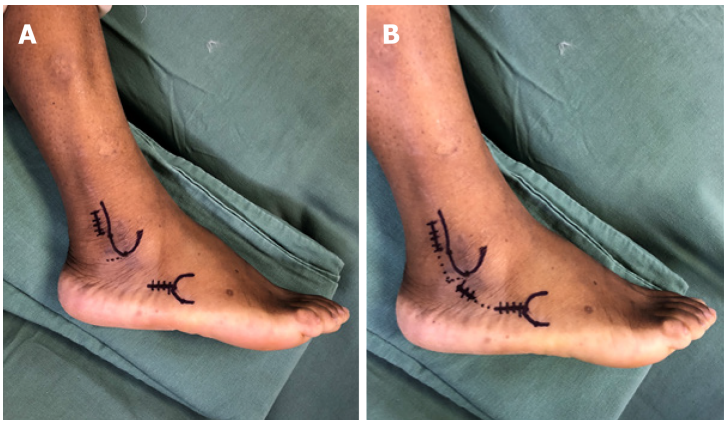

Figure 3 Preoperative skin marking of the proximal and distal incisions. A: The proximal incision was 3 cm in length, starting 1.5 cm above the tip of the lateral malleolus and 1 cm posterior to the distal fibula. Distally, a longitudinal incision of 3 cm in length was made parallel to the ground, going backwards from the tip of the base of the fifth metatarsal base. In the distal incision, the distal stump of the remaining peroneal longus tendon was dissected and released at the cuboid groove; B: Due the presence of a hypertrophic peroneal tubercle, a short middle incision of 2 cm was performed for its resection.

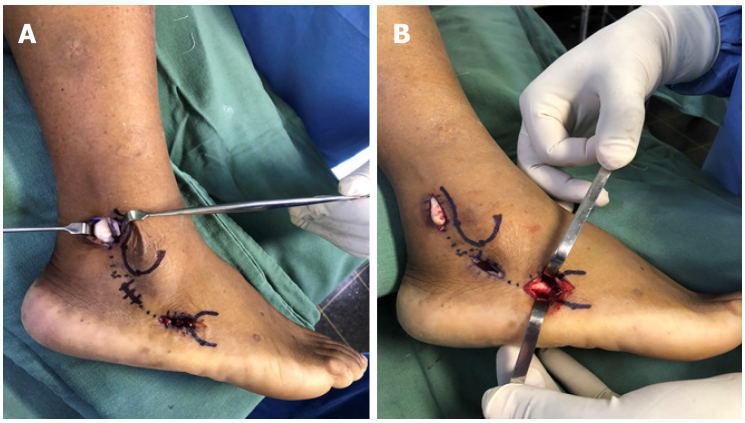

Figure 4 Intraoperative images. A: The peroneal tendon sheath was opened, preserving the superior peroneal retinaculum, and both tendons were exposed; B: The peroneal tubercle was resected through the middle incision, and the peroneus longus tendon was identified and released in the distal incision.

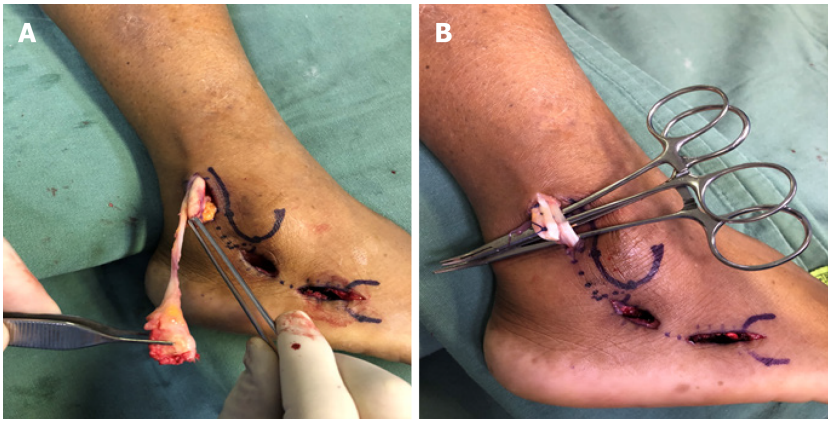

Figure 5 Tenodesis of the peroneus longus tendon to the peroneus brevis tendon. A: The peroneus longus tendon was brought out of its sheath through the proximal incision, and its nonviable portion was identified and resected; B: Side-to-side tenodesis of the peroneus longus tendon to the peroneus brevis tendon was carried out with two U-shaped lateral sutures using No. 1 Vicryl.

Figure 6 Clinical aspect at 12 wk after surgery. The surgical incisions were fully healed and swelling had decreased.

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