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Regional anaesthesia for surgical repair of proximal humerus fractures: a systematic review and critical appraisal

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Abstract

Introduction Regional anaesthesia (RA) is often used in shoulder surgery because it provides adequate postoperative analgesia and may enhance the patient outcome. RA reduces overall opioid consumption and is frequently used in enhanced recovery programs to decrease hospital stay. However, there is very limited literature confirming these advantages in the surgical repair of proximal humerus fractures. This paper reviews the current literature on the use of RA in pain management after surgical repair of these fractures and evaluates the effect of RA on the functional outcome, length of stay in hospital, and health care expenditure.

Materials and methods The PubMed, Embase, Web of Science, and Cochrane Library databases were searched up to March 1, 2018. Studies investigating the use of RA in the management of proximal humerus fractures were included.

Results Eleven studies (containing 1872 patients) were eligible for inclusion. The analgesic effect of RA was investigated in eight studies that confirmed its pain-relieving ability. Two studies measured functionality and length of hospitalization and suggested that RA improved function and shortened the stay in hospital. Nine papers mentioned side effects associated with RA while three articles claim that RA decreases the incidence of adverse events associated with general anaesthesia.

Conclusions This systematic review suggests that RA is a good option for postoperative analgesia in patients undergoing surgical repair of a proximal humerus fracture and is associated with fewer adverse events, a shorter recovery time, and a better functional outcome than those achieved by general anaesthesia alone. However, given the limited amount of data available, conclusions need to be made with caution and prospective studies are needed in the future.

Keywords Systematic review · Proximal humerus fractures · Regional anaesthesia · Postoperative outcome · Peripheral nerve block

Abbreviations

RA	Regional anaesthesia
ISB	Interscalene nerve block
ERPs	Enhanced recovery programs
LOS	Length of stay
RCTs	Randomized controlled trials
GA	General anaesthesia
PONV	Postoperative nausea and vomiting
DASH	Disabilities of the arm, shoulder, and hand
PACU	Post-anaesthesia care unit

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Introduction

Proximal humerus fractures account for 6% of all fractures in the Western world, and have increased in frequency at an annual rate of 13.7% over the past 33 years [1–3]. They are also the third most common osteoporotic fracture, in that the majority of the patients are women aged 60 years or older [2, 4]. These fractures can lead to significant pain and loss of function [5, 6].

Pain after surgery for a proximal humerus fracture is often documented as moderate to severe [6]. This postoperative pain interferes with early mobilization, physiotherapy, and patient satisfaction, and often leads to delayed discharge because of inadequate pain management and decreased shoulder functionality [7]. Regional anaesthesia (RA) in the form of an interscalene nerve block (ISB) is a common anaesthetic procedure in patients undergoing shoulder surgery and is often used for management of postoperative pain [6, 8, 9]. RA has been shown to be safe and effective for pain relief, to increase patient satisfaction, and to decrease use of opioids and their side effects [10–12]. Improving postoperative pain and the patient experience are important cornerstones of enhanced recovery programs (ERPs); both may facilitate patient participation in physical therapy, which results in more rapid recovery and a better patient outcome. Therefore, ERPs advocate use of RA to decrease the length of stay (LOS), thereby containing costs indirectly [12–14]. However, despite the extensively described advantages of RA in shoulder surgery, the published literature evaluating its beneficial effect in pain management after surgical repair of proximal humerus fractures is scarce. Furthermore, the evidence for its efficacy in terms of shoulder functionality and early patient discharge is limited [7].

The main objective was to outline the current literature on the use of RA in pain management after surgical repair of a proximal humerus fracture. The secondary aim was to evaluate the effect of RA on functional outcome, LOS, and health care expenditure in this patient population.

Materials and methods

A comprehensive search of the PubMed, Web of Science, Embase, and Cochrane Library databases was performed with the help of a biomedical information specialist. The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines were followed. The two main search concepts were proximal humerus fracture and RA. The search was limited to studies published up to March 1, 2018. The search strings are included as Supplementary material. After the primary database search, duplicate publications were removed and papers were screened based on title and abstract by two reviewers (JI, and WJM). Ambiguities were resolved by discussion with a third reviewer (SN). Figure 1 is a PRISMA flow diagram demonstrating the selection process, the number of papers retrieved, the exclusion criteria at various stages, and the number of excluded articles. The following eligibility criteria were applied: population (patients who had surgery for a proximal humerus fracture); intervention (RA for postoperative analgesia); comparator (other type of anaesthesia/analgesia); all types of outcomes; and study design. Randomized controlled and prospective or retrospective observational studies evaluating the effect of RA on outcomes after surgery for a proximal humerus fracture were included. Studies were excluded if they included patients undergoing shoulder surgery for reasons other than treatment of a fracture (e.g., arthroscopic surgery or arthroplasty), patients undergoing upper limb surgery that did not include the shoulder, and paediatric patients. Studies performed in animals or published in a language other than English were also excluded.

Results

Following assessment and confirmation of eligibility, ten papers were included in the review. Another article was identified after screening of the reference lists of the other eligible articles. Therefore, 11 articles were included in the review. Table 1 provides a general overview of the included papers and a description of the outcomes investigated. Table 2 presents an overview of the design characteristics of each study. The included studies comprised seven randomized controlled trials (RCTs), one prospective observational study, and three retrospective observational studies, together including 1872 patients. These studies only included 211 (33%) patients with proximal humerus fractures and a distinction between these and other entities was not always made (Table 1). Only two papers included a cohort consisting exclusively of proximal humerus fractures [7, 9]. Four papers did not explicitly mention the proportion of the total sample size accounted for by proximal humerus fractures [8, 10, 11, 15]. All but two of the studies used ISB as the type of RA. One of the two remaining studies used supraclavicular continuous peripheral nerve block and the other used axillary nerve block [10, 15]. The duration of follow-up ranged from 24 h to 52 weeks.

Analgesic effect of RA

Three RCTs and one retrospective observational study included an evaluation of the effect of RA combined with general anaesthesia (GA) as the primary outcome [6, 11, 15, 16]. Four of eight studies that measured pain outcomes used the visual analogue scale. In these papers, it was found that RA was sufficient for postoperative pain relief.

RA and side effects

Nine papers mentioned side effects associated with RA [6–8, 10, 11, 16–19]. Neurological complications (paraesthesia and/or motor dysfunction) were reported in six studies and respiratory side effects in five [6–8, 10, 11, 16–19]. Only Misamore et al. and Beaudet et al. documented long-term (> 6 months and > 9 months, respectively) neurological

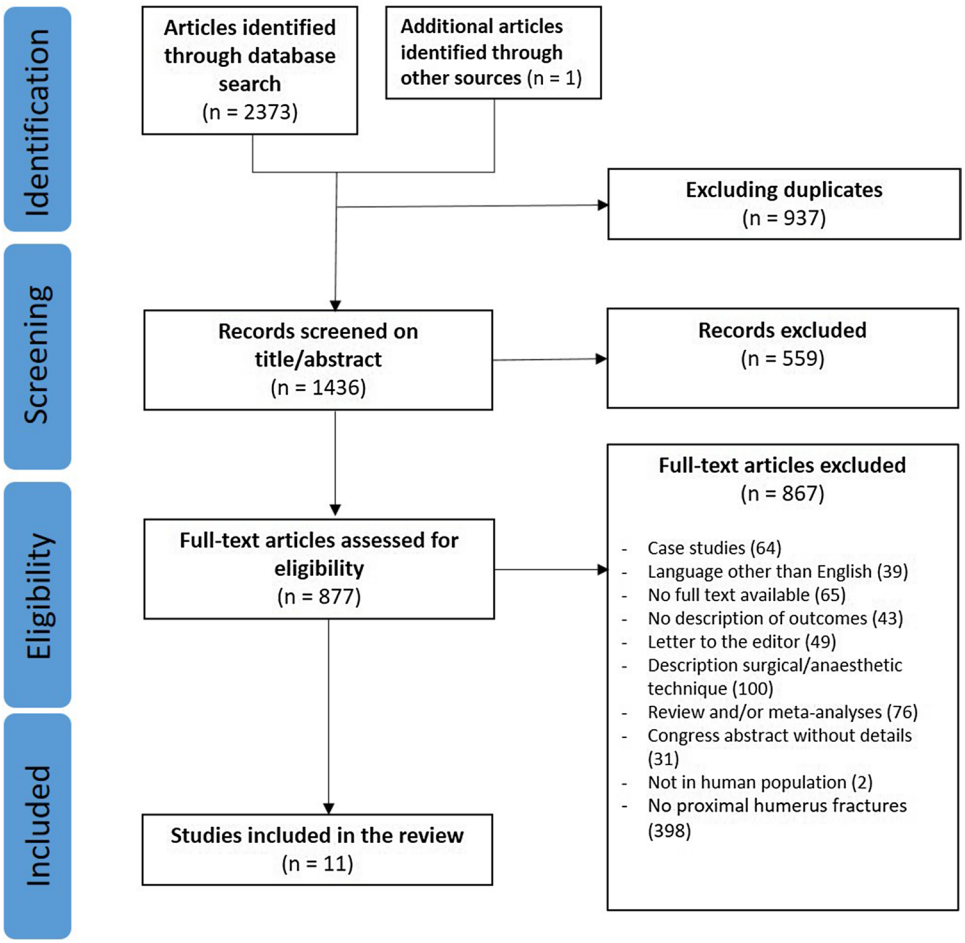

Fig. 1 PRISMA flow diagram: assessment of eligibility for inclusion in the review

complications [6, 8]. However, three articles emphasized that RA decreased the incidence of adverse events associated with GA [hypotension, postoperative nausea and vomiting (PONV)] [8, 10, 11]. Yuan et al. reported that RA significantly decreased the need for opioids and the incidence of intraoperative hypotension; however, despite the decreased use of opioids, there was no significant effect on PONV [11].

Impact of RA on functionality, LOS, and health care expenditure

Only one paper examined the influence of RA on functional outcome and range of motion after surgical repair of proximal humerus fracture [7]. In that study, use of an ISB was associated with a better functional outcome and range of motion. Patients who received RA were found to have significantly better passive and active ranges of motion and better Disabilities of the Arm, Shoulder and Hand (DASH) functional outcome questionnaire scores at the most recent follow-up. The mean duration of follow-up was 15.4 months. One study by Nallam et al. evaluated LOS in the post-anaesthesia care unit (PACU) and found that various doses of dexamethasone had no significant effect on LOS [9]. Moreover, Yuan et al. demonstrated an association between use of an ISB and a significant decrease in recovery time [11]. The study by Weber et al. was the only one that included a cost analysis [16] and found that use of an ISB was associated with a net increase in cost because of the extra time needed to perform the block and the additional charges involved.

Discussion

Restriction of shoulder mobilization is a feared outcome of inadequate pain management after shoulder surgery and imposes limitations on a patient's full functional recovery [7, 10]. RA has been found to have beneficial effects that may allow for early mobilization and early hospital discharge [7, 9, 12, 15]. This systematic review aimed to assemble the literature examining the role of RA in management of pain following surgical repair of a proximal humerus fracture and its association with functional outcome, LOS, and health care expenditure.

Table 1 General characteristics of included papers

Author	N_T	N_H	Jadad score	Demographics Age (years) Sex (F/M)	Inclusion criteria	Objective	Pain outcomes	Functional outcomes	Other outcomes	Complications	Follow-up duration
Yuan et al. (2014) [11]	100	NM	5/5	$76.7 \pm 6.3^{a,f}$ $21/29^{a}$	Elderly scheduled for upper extremity fracture surgery	To evaluate the effect of ISB combined with IV/inhalation anaesthesia compared with IV/inhalation alone	None	None	SBP/DBP Pmean HR SpO_2 Intraoperative medication use	Hypotension Mental stress Incision pain PONV	4–6 w
Oxlund et al. (2018) [17]	57	7	5/5	$59 \pm 13^{b,f}$ $24/11^{b}$	Patients scheduled for major shoulder surgery performed under GA	To investigate the pain-relieving effect of conventional continuous infusion vs. automated intermittent boluses	VAS Total amount of ropivacaine Rescue opioids PCA boluses	None	None	Horner syndrome Hoarseness Reduced cough intensity Reduced deep inspiration Paralysis of the arm	48 h
Misamore et al. (2011) [8]	573	NM	0/5	47.3 ± 16^{f} 337/573	Patients scheduled for elective shoulder surgery	To determine the rate of successful anaesthesia, duration of analgesic effect, time requirement for performance of the block, side effects, and neurological complications associated with ISB after induction of GA	Pain onset	None	Block performance time Block side effects	Persistent and long-term neurological complications Respiratory problems	10 d
Nallam et al. (2014) [9]	90	90	4/5	$46.8 \pm 4.1^{c,f}$ 21/9c	Patient scheduled for ORIF of the shoulder (Neer types 2 and 3)	To evaluate the analgesic properties of low and high doses of dexamethasone	NRS Number acetaminophen/ibuprofen Duration of analgesia	None	PACU LOS	NM	72 h

Table 1 (continued)

Author	N_T	N_H	Jadad score	Demographics Age (years) Sex (F/M)	Inclusion criteria	Objective	Pain outcomes	Functional outcomes	Other outcomes	Complications	Follow-up duration
Beaudet et al. (2008) [6]	60	3	2/5	48 ± 11[a,f] 8/22[a]	Patients scheduled for shoulder surgery	To compare ISB with IA injection	Mean NPRS Hydromorphone consumption in PACU 24-h hydromorphone consumption Static pain scores at 3, 6, 24 h postoperatively	None	1-week postoperative sensations Respiratory difficulties Satisfaction	Inadequate pain control Transient paresthesia Respiratory discomfort	24 h
Egol et al. (2014) [7]	92	92	0/5	61 ± 13.3[a,f] 34/11[a]	Patients with a displaced unstable proximal humerus fracture scheduled for ORIF	To assess the functional outcome after ORIF in patients who received either ISB or GA	None	Passive + active ROM DASH	None	Infection Screw penetration Failure of fixation Osteonecrosis Heterotrophic ossification Arthrofibrosis Painful impingement Non-union	52 w
Weber et al. (2002) [16]	218	14	0/5	55 ± 17.2[f] NM	Patients scheduled for shoulder surgery	To determine whether or not the excellent results reported in association with scalene regional anaesthesia in other studies are generalizable to the community setting	None	None	Block failure Block duration Abnormal neurological response Cost analysis	Nerve injury Grand mal seizure Cardiovascular collapse	NM
Gharabawy et al. (2014) [10]	498	NM	0/5	57 359/410	Patients discharged with a supraclavicular or popliteal catheter	To describe the experience with ambulatory continuous peripheral nerve block in regard to infection and pharmacological complications	Average daily verbal response pain score	None	Median duration of infusion	Infection Pharmacological complications Prolonged numbness Shortness of breath	5 d

Table 1 (continued)

Author	N_T	N_H	Jadad score	Demographics Age (years) Sex (F/M)	Inclusion criteria	Objective	Pain outcomes	Functional outcomes	Other outcomes	Complications	Follow-up duration
Schwenk et al. (2015) [18]	84	4	3/5	63.8[d] 17/25[d]	Patients scheduled for open shoulder surgery	To compare the out-of-plane technique with the in-plane technique	VAS Morphine consumption Number PCA boluses	None	None	PONV Dizziness Tinnitus	48 h
Flory et al. (1995) [19]	40	1	2/5	51 (21–82)[e,g] 11/9[e]	Patients with chronic shoulder pain for which surgical treatment was necessary	To assess the peripheral effects of opioids on postoperative analgesia	VAS Time to first analgesic Pain intensity Number and total doses of analgesics	None	Patient satisfaction SaO_2 FiO2 FE(CO)2	Diaphragmatic paralysis Dyspnea Horner syndrome PONV Thoracic pruritus	48 h
Alimohammedi et al. (2014) [15]	60	NM	2/5	38.1 ± 19.4[a,f] 9/2[a]	Patients with upper extremity fractures scheduled for fracture reduction	To compare the analgesic effects of axillary nerve block vs IV midazolam/fentanyl	VAS Severity of pain at baseline Severity of pain during procedure Severity of pain after 30 min	None	Procedure initiation time Procedure completion time Rate of onset of anaesthesia Recovery time	None	30 h

DBP diastolic blood pressure, $FE(CO)_2$ fractional expired carbon dioxide concentration, FiO_2 fractional inspired oxygen concentration, *GA* general anaesthesia, *HR* heart rate, *ISB* interscalene brachial plexus block, *IV* intravenous, N_T total number of study participants, N_H total number of patients with fractures of the proximal humerus, *NM* not mentioned, *NPRS* numeric pain rating scale, *ORIF* open reduction and internal fixation, *PCA* patient-controlled analgesia, P_{mean} mean arterial pressure, *PONV* postoperative nausea and vomiting, SaO_2 peripheral oxygen saturation, *SBP* systolic blood pressure, SpO_2 peripheral oxygen saturation, *VAS* visual analogue scale, *min* minutes, *h* hours, *d* days, *w* weeks, *PACU* post-anaesthesia care unit, *LOS* length of stay, *IA* intra-articular, *ROM* range of motion, *DASH* disabilities of the arm, shoulder and hand, *F* female, *M* male, *n* number, *ASA* American Society of Anesthesiologists

[a]Age and sex related to the RA group

[b]Age and sex related to the continuous infusion group

[c]Age and sex related to the group with the highest dose dexamethasone

[d]Age and sex related to the out-of-plane group

[e]Age and sex related to the group with morphine

[f]Age documented with standard deviation

[g]Age documented with range

Table 2 Study design characteristics

	n	References
Type of regional anaesthesia		
ISB	9	[6–9, 11, 16–19]
Supraclavicular continuous peripheral nerve block	1	[10]
Axillary nerve block	1	[15]
Study design		
RA + GA vs GA alone	4	[6, 11, 15, 16]
Continuous vs intermittent bolus RA	1	[17]
Varying doses of dexamethasone	1	[9]
Addition of morphine	1	[19]
In-plane vs out-of-plane technique	1	[18]
RA alone vs GA alone	1	[7]
RA + GA (descriptive)	1	[8]
RA (descriptive)	1	[10]
Outcome measures		
Pain	8	[6, 8–10, 15, 17–19]
Function	1	[7]
Other	9	[6, 8–11, 15, 16, 18, 19]
LOS	1	[9]
Cost analysis	1	[16]
Side effects	9	[6–8, 10, 11, 16–19]
Short-term and/or long-term nerve damage	5	[6, 8, 10, 16, 17, 19]
Respiratory side effects	4	[6, 8, 10, 17, 19]
PONV	2	[11, 18, 19]
Hypotension	1	[11]

GA general anaesthesia, *ISB* interscalene block, *LOS* length of stay, *PONV* postoperative nausea and vomiting, *RA* regional anaesthesia

Analgesic effect of RA

Of the 877 papers screened for inclusion, only 11 investigated the use of RA in surgery for a proximal humerus fracture. These papers reported that RA, predominantly ISB procedures, provided substantial postoperative analgesia and allowed a shorter recovery time. These findings are substantiated in similar but more recent reviews by Huang et al. and Kessler et al. who found that ISB was associated with better analgesia after shoulder surgery and greater patient satisfaction than other analgesia techniques [20, 21].

Single-shot ISB is now widely considered to be the gold standard for pain relief in shoulder surgery and offers effective pain control for up to 8 h after administration [22, 23]. However, there are several problems with single-shot ISB. First, major shoulder surgery is associated with pain that can last for up to 48 h. Moreover, the pain after fracture surgery is expected to last even longer because of the accompanying tissue damage. Second, single-shot ISB seems to be associated with rebound pain that develops at 16–24 h postoperatively. One option to address these problems is the use of a continuous nerve block that provides prolonged pain relief [23]. Another solution could be to add adjuvant agents to prolong the analgesic effect for up to 24 h [8, 9, 16, 17]. Nallam et al. reported that dexamethasone significantly prolongs and improves analgesia, whereas Flory et al. could not demonstrate a higher quality of analgesia nor better patient satisfaction when ISB was combined with morphine [9, 19].

The recent meta-analysis by Baeriswyl et al. favors perineural over systemic administration of dexamethasone [24]. However, despite these data, there are still no recommendations regarding adjuvants for perineural use; use of drugs in this way is still considered 'off-label' when they are mixed with local anaesthetics [24, 25]. Finally, according to recently published data, liposomal bupivacaine provides analgesia for up to 72 h [25–27]. RCTs on the use of liposomal bupivacaine in brachial plexus blocks are ongoing.

RA and side effects

There have been concerns that RA, and ISB in particular, is associated with nerve damage and a deterioration in respiratory function [8, 11, 28–30]. The most common side effect is ipsilateral phrenic nerve block, which has been reported to occur in up to 100% of cases [8, 31]. The incidence of definite neurological symptoms appears to be low, with

99.3–100% recovery before 11 months [25, 32, 33]. Adverse events associated with ISB were found in 9 of the 11 papers included in the present review [6–8, 10, 11, 16–19]. All nine studies mentioned neurological complications. Five of the nine studies documented respiratory side effects attributed to phrenic nerve dysfunction, associated with RA [6, 8, 10, 16, 17, 19]. All these side effects were temporary pharmacologic blocks and most resolved within 48 h. Only Weber et al. mentioned one grand mal seizure and cardiovascular collapse due to phrenic nerve injury. Other exceptions were the study by Misamore et al., who documented that ISB was associated with a 0.8% long-term (> 6 months) neurological complication rate, confirmed by electromyography (EMG) and Beaudet et al., who reported one patient with persistent paraesthesia in the first, second, and fifth finger of the operated limb that persisted over 9 months [6, 8].

However, the safety and popularity of this technique have increased as a result of ultrasound-guided placement, which lowers the risk of respiratory complications [8, 10, 11, 13, 28]. Moreover, research has demonstrated that more experience and technical expertise have been associated with fewer complications [8, 16].

Furthermore, RA decreases the incidence of adverse events associated with GA [8, 10, 11, 34, 35]. The PONV often associated with use of opioids is decreased in patients who receive RA [10, 34, 36, 37]. The study by Yuan et al. demonstrated that combination of an ISB with GA is associated with less severe adverse effects and less use of intraoperative and postoperative opioids [11]. Importantly, lowering inpatient opioid use decreases the number of opioid prescriptions required at discharge, which is a major issue in some areas of the world [38]. However, in accordance with other reports a significant relationship between decreased use of opioids and a reduction in PONV could not be demonstrated [23, 39, 40].

Shoulder surgery is often performed in the beach chair position, which is associated with a high risk of hypotension. Several factors associated with GA aggravate the decrease in blood pressure [41]. The effect of an additional ISB on the average decrease in blood pressure is not consistent. Yuan et al. reported that the decrease in blood pressure was less pronounced with RA than with GA [11, 41] whereas other studies found a more marked decrease in systolic blood pressure when GA was combined with an ISB [41–43].

When single-shot ISB is used, the risk of side effects can be decreased by lowering the dose of local anaesthetic administered [16, 17, 25]. While continuous blocks provide prolonged postoperative analgesia, they are also associated with more adverse events [23, 25]. Nevertheless, practitioners should be aware that some of these side effects are related to the operative procedure or factors other than the anaesthetic technique [25]. The findings of a study by Vorobeicik et al. support use of a continuous block for at least 48 h after shoulder surgery, but with the caveats that appropriate informed consent is necessary and the advantage needs to be balanced against the potential risk, especially in patients with compromised pulmonary function [16, 22, 23].

Impact of RA on function, LOS, and health care expenditure

As already mentioned, RA prolongs the duration of postoperative pain relief, decreases the risks of the side effects that occur with GA (e.g., PONV), reduces oral opioid requirements, and increases patient satisfaction. These advantages may enable early mobilization and decrease the time to discharge [10, 12, 13, 35, 44]. In this systematic review, only the study by Egol et al. examined the effect of RA on early mobilization in patients undergoing surgical repair of a proximal humerus fracture. Patients who had received an ISB had a significantly better functional outcome, range of motion, and DASH score than those who had received GA. This effect can be attributed to prolonged postoperative pain relief, which allows patients to proceed with earlier and more intensive physiotherapy. Previous studies in other types of surgery have demonstrated that early mobilization can reduce LOS because of the decreased need for nursing services or care [14, 45]. Therefore, the favorable effect of RA on mobilization can be exploited in the context of ERPs. These patient-centered, evidence-based, and cost-effective programs have become important in high-throughput hospitals [13]. Despite the fact that ERPs have been studied extensively in other types of surgery, including for hip fracture and shoulder arthroplasty, there are no clear and consistent conclusions in the population with proximal humerus fractures. These patients differ from those undergoing elective shoulder surgery in that fractures at this site are associated with extensive soft tissue damage and more severe pain; therefore, adequate postoperative pain management is particularly important.

As previously mentioned, the majority of patients with a proximal humerus fracture are geriatric [2, 4]. Compared to the younger population, they are more sensitive to adverse side effects of anaesthetics [11, 45]. Elderly patients have specific management needs due to the higher risk of cardiovascular, neurologic and pulmonary complications, which makes them a number one requesting party for ERPs [11, 14, 46, 47]. Literature on ERPs in elderly suggests that these protocols are safe, beneficial for older and frail patients and render improved outcomes [47, 48]. However, data are still sparse and more well-designed clinical trials are needed for this group and trauma surgery in general. As the worldwide population is aging, it seems important that physicians are aware of this. Based on current literature we believe that RA and ERPs would better

serve the ortho-geriatric population, thanks to frailty assessment and tailored discharge strategy [49].

Only one of the studies included in this systematic review reported on LOS and its relationship with use of RA in the treatment of proximal humerus fractures [9]. This was the study by Nallam et al., who demonstrated that use of an ISB did not decrease LOS in the PACU. However, this result is in contrast with the reports by Abdallah et al. and Yuan et al., who found that RA was associated with a shorter recovery time [11, 22]. The literature also suggests that use of a portable infusion pump further shortens the LOS and provides additional benefits after discharge. Reducing the LOS is important in terms of health care expenditure. As mentioned earlier, shoulder surgery is associated with moderate to severe postoperative pain, and GA has several side effects that may not only lead to delayed discharge but also to unanticipated readmissions, both of which increase health care costs [12, 45, 50, 51].

To our knowledge, there has been no comprehensive cost balance between RA and GA for surgical repair of a proximal humerus fracture in terms of LOS. However, the paper by Weber et al. did include a cost analysis, which demonstrated that RA was associated with a net increase in health care expenditure [16]. However, they did not take into account the fact that RA reduces both postoperative pain and the incidence of opioid-related side effects, which facilitates early participation in an exercise program, resulting in more rapid recovery and an overall reduction in health care costs [11, 12]. The importance of early discharge from hospital has been underscored by several investigators, who have pointed out that prolonged hospitalization increases the risk of hospital-acquired infection and other adverse events as well as the input needed by hospital staff, both of which are associated with additional costs [14, 52].

Limitations

This systematic review has some limitations. First, despite the increasing use of RA in shoulder surgery, the limited number of studies eligible for inclusion in this systematic review preclude drawing of any clear conclusions on the role of RA in the management of pain after surgical repair of a proximal humerus fracture. Second, the studies included had variable designs, objectives, follow-up intervals, and outcome measures, which made it difficult to formulate any assumptions. Finally, only two studies included a patient population with proximal humerus fractures alone.

Conclusion and future perspectives

Few studies have investigated the use of RA for analgesia after surgery for a proximal humerus fracture. The literature, albeit sparse, indicates that RA is a good choice for postoperative analgesia and is associated with fewer adverse events, a better functional outcome, and a shorter recovery time than GA alone [7, 11, 15]. The available evidence supports the use of a continuous ISB for major shoulder surgery and potentially addition of corticosteroids to prolong the analgesic effect of single-shot ISB [23].

Well-designed prospective RCTs are required to substantiate the tentative conclusions made in this systematic review. These studies should include functional outcome measures, including range of motion and functional outcome questionnaire scores (DASH or Constant), hospital LOS, economic indicators, and patient satisfaction. In the meantime, clinicians can regard RA as an effective method of delivering analgesia that can optimize recovery and improve patient functionality. Both these factors can contribute to a decreased LOS and improved patient satisfaction in the context of ERPs for patients who have sustained a proximal humerus fracture.

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Compliance with ethical standards

Conflict of interest Prof. Dr. An Sermon is a consultant for DepuySynthes. Prof. Dr. Willem-Jan Metsemakers is a consultant for DepuySynthes and BoneSupport. Furthermore, he is a member of the lecture bureau of Zimmer Biomet. Prof. Dr. Stefaan Nijs is consultant for DepuySynthes, Zimmer Biomet and Mathys Medical. Prof. Dr. Harm Hoekstra is a member of the lecture bureau of DepuySynthes and 7Smedical. All authors hereby disclose any financial and personal relationships with other people or organisations that could inappropriately influence this work.

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