BRITISH JOURNAL OF HOSPITAL MEDICINE

REVIEW

When can anterior dislocations of the shoulder with an isolated fracture of the greater tuberosity be safely reduced in the emergency department?

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Abstract

Following dislocation of the glenohumeral joint with an isolated greater tuberosity fracture, closed reduction in the emergency department can lead to fracture propagation or iatrogenic fractures. This article assesses the evidence regarding when anterior dislocations of the shoulder with an isolated fracture of the greater tuberosity can be safely reduced in the emergency department, as there is currently no clear guidance on this. A total of eight articles described 172 cases which underwent closed reduction, which resulted in 22 cases of iatrogenic fractures. Female sex, increased patient age and fragments of the greater tuberosity were associated with an increased risk of iatrogenic fractures. Closed reduction in the emergency department appears to be a safe option in younger patients and those with greater tuberosity fractures less than 40% of the width of the humeral head.

Key words: Closed reduction; Dislocation; Emergency department; Fracture-dislocation; Glenohumeral; Iatrogenic fracture; Shoulder; Subluxation

Submitted: 25 May 2021; accepted following double-blind peer review: 9 December 2021

Introduction

The glenohumeral joint is the most common joint to experience acute dislocation owing to its intrinsic flexibility and instability (Kao et al, 2018). Anterior shoulder dislocations are commonly associated with clinically significant fractures of the greater tuberosity – a combination that is believed to greatly increase the risk of iatrogenic humeral neck fractures during reduction (Atoun et al, 2013; Atef et al, 2016; Wronka et al, 2017; Guo et al, 2019). Cases of three-part and four-part iatrogenic fractures have been documented, with the associated complication of avascular necrosis and poor postoperative outcomes (Ferkel et al, 1984; Hersche and Gerber, 1994; Robinson et al, 2006; Ranawat et al, 2007).

Treatment options include non-operative management via closed reduction (commonly performed in the emergency department with appropriate analgesia and sedation) and operative approaches (primarily open reduction with internal fixation) (Wronka et al, 2017). As it is widely acknowledged that an incongruent shoulder should be promptly reduced, dislocation of the glenohumeral joint with an isolated greater tuberosity fracture presents a clinical dilemma, and it is unclear if closed reduction in the emergency department is a safe option. The influence of patient factors, including age, sex and mechanism of injury, on the risk of fracture propagation is unclear, and it is not known if this risk is influenced by the reduction method or the number of attempts at reduction.

With the absence of clinical guidelines, at present, clinicians have to undertake an individualised risk assessment for closed reduction under sedation based on limited evidence. This review provides a descriptive summary of available evidence regarding management of dislocations of the glenohumeral joint with an isolated greater tuberosity fracture in the emergency department.

Methods

This review was undertaken in accordance with Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines. Original studies based on the following criteria

How to cite this article:
Effiom DN, Bartlett JD, Raja H, Aresti N. When can anterior dislocations of the shoulder with an isolated fracture of the greater tuberosity be safely reduced in the emergency department? Br J Hosp Med. 2022. https://doi.org/10.12968/hmed.2021.0309

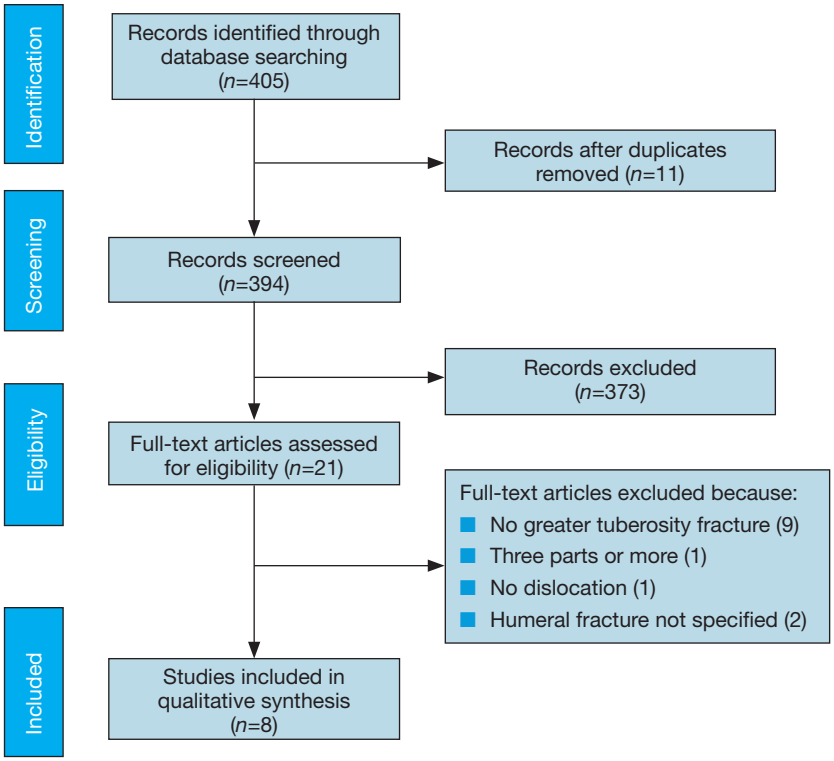

Figure 1. A flowchart showing the selection of studies for inclusion in the systematic review.

were eligible for this review: publication in an English language journal and management of isolated fractures of the greater tuberosity with concomitant anterior glenohumeral dislocation. Articles that discussed the specific management of posterior dislocations, chronic dislocations, isolated surgical neck fracture, isolated anatomical neck fractures and fracture of the glenoid were excluded.

A literature search of journal articles using the MEDLINE, Embase and Google Scholar databases was performed in November 2019. No date restrictions were placed. The literature search began with the search ('fracture' AND 'dislocation') OR 'fracture-dislocation'. This initial subset was then searched using ('shoulder' OR 'glenohumeral') AND 'anterior'.

All articles were screened to assess appropriateness according to the criteria (Figure 1). Then, full review was undertaken by two authors (DE and JB) to extract the following information where possible: quality of the study, age and sex of patient, type of dislocation, reduction method, number of attempts at closed reduction, analgesia and/or sedation used, use and timing of open reduction and internal fixation (if applicable) and complications.

Risk of biases, summary of results and synthesis of results were not applicable for this review.

Results

A total of 405 relevant titles were identified, published between 1846 and 2019 (Figure 1). After removal of duplicates, screening for irrelevant studies, eight articles remained, of which five were retrospective cohort studies and three were case series. No prospective studies were identified. All studies met the inclusion criteria and are summarised in Table 1. The quality of evidence was low in all articles.

Retrospective studies

Within the retrospective studies, 168 cases of anterior dislocation of the proximal humerus with concomitant fracture of the greater tuberosity underwent closed reduction in the emergency department (Table 1). Of these, 18 developed iatrogenic fractures of the surgical neck. By analysing pre-reduction anterior-posterior shoulder radiographs, one retrospective cohort study demonstrated a significant relationship between the size of the greater tuberosity

fragment and the risk of iatrogenic fracture (Guo et al, 2019). Using this technique, they categorised fragments with a width >40% the width to the humeral head to be unstable and at high risk of iatrogenic fracture (Figure 2). The apex of greater tuberosity (A) was used as a reference point, from here the distance to the maximum medial curvature of the

Table 1. Retrospective cohort studies of the management of fracture dislocations of the proximal humerus with an isolated greater tuberosity fracture

Reference	Number of cases of anterior dislocation with isolated greater tuberosity fracture	Reduction method and number of attempts	Findings	Conclusions
Guo et al (2019)	76 cases (33 reduced in the emergency department) Average age 52.4 years (range 18–84 years) 40 male, 36 female	Modified Hippocratic method Number of attempts not specified	Significant relationship exists between the size of the greater tuberosity fragment and risk of iatrogenic fracture Women were found to have a higher risk of iatrogenic fracture Increased risk of iatrogenic fracture if >49 years old	Risk of iatrogenic fracture was present in both manual reduction and open reduction internal fixation Authors recommend 'unstable fractures' be treated with prophylactic stabilisation before gentle reduction
Wronka et al (2017)	51 cases Average age of cases and male:female ratio not given	Hippocratic or traction or countertraction One attempt at reduction 10 primary cases performed under general anaesthetic	Three reductions unsuccessful requiring general anaesthesia No cases of fracture propagation	Authors advise that attempts at closed reduction under sedation can be made with isolated greater tuberosity fractures Authors found a high rate of fracture propagation (40%) in the presence of surgical neck with concomitant greater tuberosity fractures
Atoun et al (2013)	19 cases Average age of cases and male:female ratio not given	Reduction method and number of attempts not specified	Five patients developed iatrogenic neck fractures (all had greater tuberosity fracture on initial X-ray) All patients who developed iatrogenic neck fractures had poor clinical outcomes	Highly significant association with greater tuberosity fracture and iatrogenic post-reduction fracture Authors strongly recommend treating patients older than 40 years with a first-time dislocation under general anaesthesia with full relaxation
Hébert-Davies et al (2015)	55 cases Average age 63.1 years (range 27–94 years) 28 male, 27 female	Reduction method and number of attempts not specified	No iatrogenic fractures were found in their population. Four were irreducible, three of which required open reduction with internal fixation and one of which was managed with closed reduction under anaesthesia	Significant reduction in fragment displacement on post-reduction X-rays (26 mm to 3 mm) Nine patients developed secondary displacement of the greater tuberosity fragment with three requiring open reduction with internal fixation. This was 5.6 times more likely in those over 70 years old Authors advised close follow up with serial X-rays for the first several weeks to allow for early surgical intervention if warranted in patients under 70 years old
Perron et al (2003)	10 cases Average age of cases and male:female ratio not given	Reduction method and number of attempts not specified	No iatrogenic fractures were found in their population	Iatrogenic fracture is rarer than in the general population as a result of reporting bias

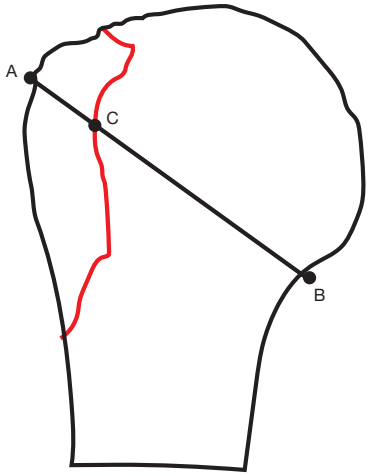

Figure 2. A schematic detailing how the width of a greater tuberosity fragment was measured. The apex of greater tuberosity (A) was used as a reference point, from here the distance to the maximum medial curvature of the humeral neck (B) and the fracture line (C) were measured, to give AB and AC respectively. The ratio of AC:AB was used in determining the stability of the humeral head. From Guo et al (2019).

humeral neck (B) and the fracture line (C) were measured, to give AB and AC respectively. The ratio of AC:AB was used in determining the stability of the humeral head.

Guo et al (2019) also noted an increased risk of iatrogenic fracture in female patients and those above 49 years old when undergoing closed reduction under sedation. A significant risk of iatrogenic fracture was also demonstrated in patients older than 40 years old with first-time dislocation, with poor outcome demonstrated in patients who developed iatrogenic neck fractures (Atoun et al, 2013). Conversely, three studies found no cases of iatrogenic surgical neck fracture in patients undergoing closed reduction under sedation (Perron et al, 2003; Hébert-Davies et al, 2015; Wronka et al, 2017).

Case series

Two of the three case series in the literature described a total of four cases in which anterior dislocation of the shoulder joint with an isolated fracture of the greater tuberosity was converted to three-part or four-part fractures as a result of closed reduction (Ferkel et al, 1984; Ranawat et al, 2007; Solovyova et al, 2017) (Table 2). One case series of 12 patients found no cases of iatrogenic fractures with a variety of reduction manoeuvres. In one case series, a further two cases of presumed iatrogenic fractures were found to have undisplaced surgical neck fracture on pre-reduction radiographs after retrospective review of reduction radiographs (Ranawat et al, 2007).

Discussion

The optimal management of fracture dislocations of the proximal humerus with an isolated greater tuberosity fracture remains an area of controversy because of the concerns of iatrogenic fracture propagation and conversion to a three- or four-part proximal humerus fracture (Ferkel et al, 1984; Ranawat et al, 2007; Atoun et al, 2013; Atef et al, 2016; Wronka et al, 2017; Guo et al, 2019). The development of this complication can be disastrous, owing to the increased risk of avascular necrosis and reports of poor outcomes within this patient group (Ranawat et al, 2007; Atoun et al, 2013). Several retrospective cohort studies have attempted to provide insight into those groups most at risk of iatrogenic fractures during closed reduction in the emergency department through analysis of patient demographics and pre-reduction radiographic features (Atoun et al, 2013; Wronka et al, 2017; Guo et al, 2019).

Atoun et al (2013) retrospectively analysed the prevalence of iatrogenic fractures on post-reduction radiographs in 92 patients older than 40 years with first-time dislocations at their centre. They found a highly significant association between the presence of a pre-reduction greater tuberosity fracture (present in 19 cases) and a post-reduction displaced humeral neck fracture in the five patients who developed this complication (5.4% of all reductions, 26.3%

Table 2. Case series reporting iatrogenic fractures following closed reduction under sedation for fracture dislocations of the proximal humerus with an isolated greater tuberosity fracture

Reference	Number of cases of anterior dislocation with isolated greater tuberosity fracture	Reduction method and number of attempts	Findings	Conclusions
Ranawat et al (2007)	Two cases: 89-year-old man and 50-year-old woman	Reduction method not specified One case had multiple attempts (number not specified)	One surgical neck One conversion to three-part fracture	Authors highlight need for careful radiological examination One case had multiple attempts at closed reduction Further two cases had missed humeral neck fractures that were converted to three-part and four-part fractures
Ferkel et al (1984)	Two cases: 59-year-old man and 52-year-old woman	One underwent two attempts with traction-countertraction One underwent one attempt with traction-countertraction	Two converted to three-part fracture	Authors advise gentle closed reduction under fluoroscopic guidance in operating theatre and open reduction with internal fixation if closed reduction fails
Solovyova et al (2017)	12 cases: all over 50 years old	Reduction methods included traction-countertraction (53%), reverse Stimson (31%), Stimson (8%), Milch (8%) Initial attempt successful in all cases	No iatrogenic fractures nor fracture propagation were found on post-reduction X-rays	Authors concluded that an initial attempt at closed reduction is safe in the emergency department, but could not specify the number of closed reductions deemed appropriate before escalation

of reduction with greater tuberosity fracture). All five of these patients had poor outcomes and multiple major complications, regardless of initial operative management. Given the high rates of iatrogenic fracture, the authors recommend that all patients over 40 years old with a greater tuberosity fracture on pre-reduction radiographs should undergo closed reduction under general anaesthesia and full relaxation. Owing to limited documentation, the authors were unable to comment on the reduction techniques used or the number of reduction attempts used in their cohort. These may be important confounding factors that limit the generalisability of these results and conclusions drawn from this dataset.

Patient age was also found to be an important predictive factor in Guo et al (2019)'s retrospective analysis of 76 cases of anterior shoulder dislocation with greater tuberosity fracture, of which 33 underwent closed reduction. The remaining 43 were managed with open reduction with internal fixation in the first instance with no attempt at manual reduction. In this study, female patients and patients aged 50 years or older were found to be high-risk groups for the development of secondary fracture, even when these patients underwent open reduction with internal fixation. The authors attributed this increased risk to age- and sex-related risk factors such as osteoporosis. It is likely that postmenopausal women are at higher risk of iatrogenic fracture given the lack of protective effects of oestrogen on their bone mineral density and the higher rates of osteopenia and osteoporosis. Patients who underwent open reduction with internal fixation were also at higher risk of iatrogenic surgical neck fracture than those who underwent closed reduction. This study also found a highly significant relationship between the size of the greater tuberosity fragment and the risk of iatrogenic fracture. They defined greater tuberosity fragments of >40% than the total width of the humeral head to be unstable and at high risk of iatrogenic fracture, regardless of the initial management (94.4% sensitivity and 91.4% specificity for development of surgical neck fracture upon reduction). For these unstable fractures, the authors advocated operative management with prophylactic surgical stabilisation with Kirschner wires to reinforce the proximal humerus before gentle closed reduction. These recommendations are echoed by the authors of two case series on the basis of their experiences with the conversion of isolated greater tuberosity fractures to three-part proximal humerus fractures (Hersche and Gerber, 1994; Ranawat et al, 2007).

However, the generalisability of Guo et al's (2019) results is limited. Although these results were retrospectively validated in the study's cohort, prospective validation of this radiographic threshold is required before widespread adoption can be justified. Additionally, all closed reductions attempted in this study were conducted under analgesia, not conscious sedation or intra-articular injection as recommended by previous studies (Ferkel et al, 1984; Wronka et al, 2017). These previous studies have highlighted concerns that iatrogenic injuries can occur in cases of insufficient relaxation and vigorous reduction manoeuvres. Furthermore, there may be important confounding factors as the reduction method and the number of attempts were not included in the authors' analysis.

In contrast, three further retrospective studies found no risk of iatrogenic fracture in their study cohorts. Wronka et al (2017) noted no cases of iatrogenic fracture in 51 patients who underwent one attempt at closed reduction using a modified Hippocratic method. They also reported a high success rate, with only three patients requiring subsequent reduction on general anaesthesia. This study demonstrates that a single attempt at closed reduction under sedation using the modified Hippocratic method may be a safe management option.

Hébert-Davies et al (2015) found no cases of iatrogenic fracture in their retrospective analysis of 55 cases of anterior fracture dislocations initially managed with closed reduction under sedation. Irreducible dislocation was seen in four of these cases: three of which were managed with open reduction with internal fixation and one with closed reduction under anaesthesia. This study did not report the reduction methods used and it is unclear how many attempts were undertaken before a case was deemed irreducible.

Perron et al (2003) argued that there is a publication bias in the literature, given the low incidence of fracture dislocations that they found in their emergency department population. They reported 10 cases of greater tuberosity fracture that successfully underwent closed reduction with no complications during reduction. However, this conclusion is significantly limited, as not all of the patients received post-reduction radiographs and subsequent follow up was not included in the analysis.

Two case series described four cases of fracture dislocations with isolated greater tuberosity fracture that developed an iatrogenic surgical neck fracture or were converted to a four-part proximal humerus fracture (Ferkel et al, 1984; Ranawat et al, 2007). Two of these cases were documented to have undergone multiple reduction attempts (Ferkel et al, 1984; Ranawat et al, 2007). One case series also reported two cases of humeral neck fracture propagation that were attributed to a missed fracture on pre-reduction radiographs, again highlighting the importance of thorough examination of radiographs before reduction (Ranawat et al, 2007). Although these cases provide low-level evidence, they do highlight the potential risks of closed reduction in the presence of a greater tuberosity fracture.

Based on the available evidence the authors recommend that emergency departments stratify patients into high and low risk to determine their initial management. Patients presenting with an anterior glenohumeral dislocation and isolated concomitant greater tuberosity fracture should be assessed to see if the greater tuberosity fracture fragment is >40% of the width of the humerus. If unsure further imaging such as a computed tomography scan should be obtained. If the greater tuberosity fracture is >40% of the width of the humerus, the patient should be referred to the orthopaedic team for open or closed reduction in theatre. If a greater tuberosity fragment of <40% of the width of the humerus is confirmed, the patient should be assessed for the presence of any of the following risk factors: osteoporosis, post-menopausal female, age over 50 years, any of which confers higher risk. Low-risk patients are suitable for one attempt at reduction under simple analgesia. High-risk patients should have one attempt of reduction under sedation by an appropriately trained emergency department or orthopaedic physician. If a low-risk patient fails one attempt at a simple reduction, reduction under sedation in the emergency department should be trialled. If this attempt fails, these patients should be referred to orthopaedics for an open or closed reduction under a general anaesthetic (**Figure 3**).

Limitations

Any conclusions drawn from this literature review are limited by the absence of published prospective studies regarding the management of fracture dislocations of the proximal humerus. There are only a small number of single-centre retrospective studies, with a

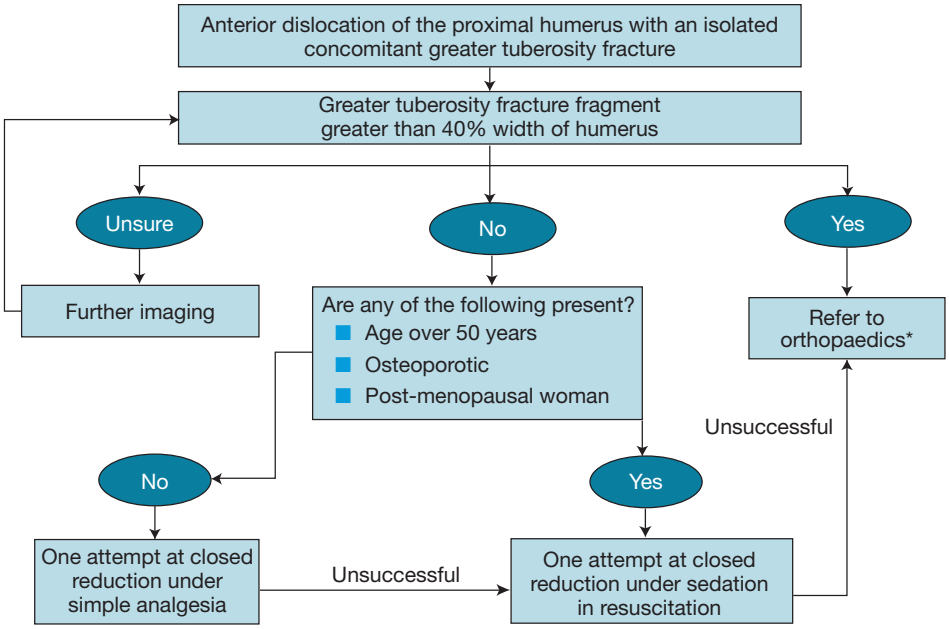

Figure 3. Proposed management algorithm for emergency departments. *The authors recommend closed or open reduction under general anaesthesia.

small total number of patients. Multicentre prospective studies are required to provide further information about the best approach to manage this patient group and to validate suggestions of patient groups most at risk of iatrogenic surgical neck fracture.

Only one retrospective study reported the reduction type and number of attempts for their patient cohort. These are two important variables that may contribute to the development of iatrogenic fracture. As such, future prospective studies should aim to include these in their analysis to provide further information regarding the safest techniques and number of attempts that can safely be performed. The authors recommend that future analysis categorises variables in patient factors, reduction factors and radiographic factors (**Figure 4**) to enable multivariant analysis and prevent the contribution of undocumented confounding factors.

Conclusions

A limited number of retrospective studies have identified several potential risk factors for the development of iatrogenic fractures during closed reduction. Closed reduction in the emergency department appears to be a safe management option in younger patients and those with greater tuberosity fractures less than 40% the width of the humeral head.

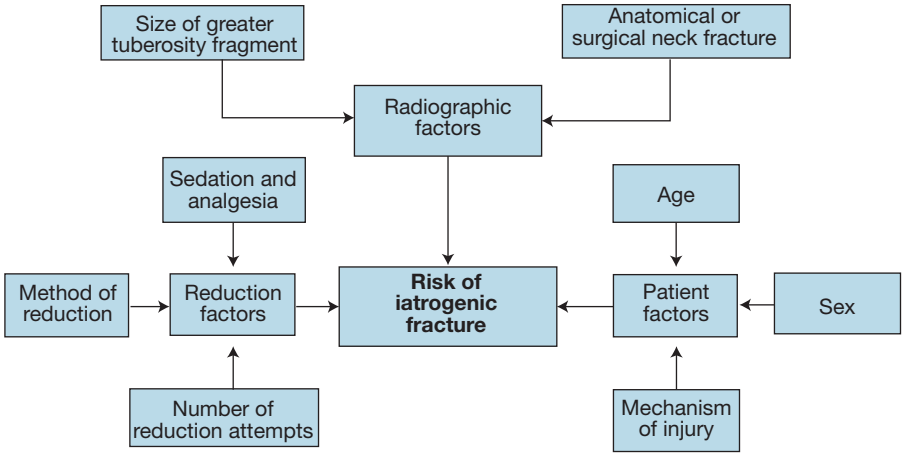

Figure 4. Categorisation of variables that influence the risk of iatrogenic fracture following closed reduction in patients with fracture dislocations of the proximal humerus with an isolated greater tuberosity fracture.

Key points

- There is no consensus as to when anterior shoulder dislocation with greater tuberosity fractures can safely be reduced in the emergency department.
- Increased patient age, female sex and greater tuberosity fragments >40% of the width of the humeral head were associated with an increased risk of iatrogenic fractures in the literature.
- Prospective studies with documentation of patient factors, reduction factors and radiographic factors are required to provide further insight into the best management of this condition.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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