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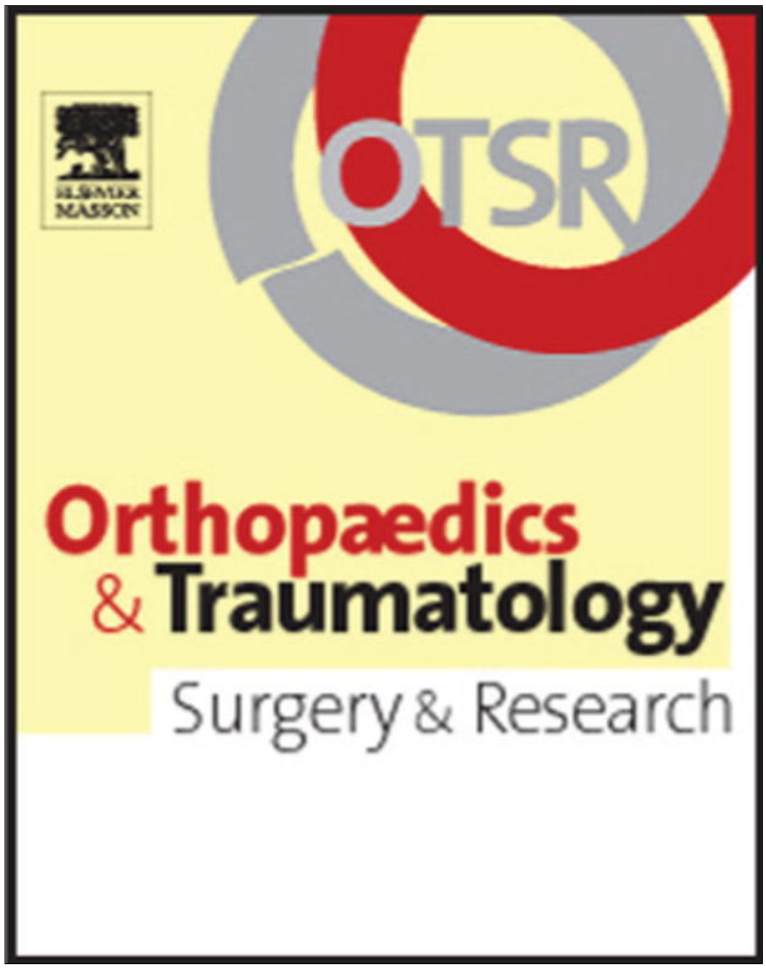

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ORIGINAL ARTICLE

Reverse shoulder arthroplasty combined with a latissimus dorsi and teres major transfer for a deficit of both active elevation and external rotation. Results of 15 cases with a minimum of 2-year follow-up☆

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Summary
Purpose: Our aim was to assess the clinical and radiological outcomes of reverse shoulder replacements performed in association with a latissimus dorsi and teres major tendon transfer in cases of irreparable posterosuperior cuff tears including the teres minor tendon. Our hypothesis was that the tendon transfers would improve the clinical results of arthroplasty by restoring active external rotation.
Methods: Fifteen procedures in 14 patients were performed through a single deltopectoral approach. Both tendons were fixed to the proximal anterolateral aspect of the humeral metaphysis. Mean age at the time of surgery was 67.5 years (range 53 to 82 years). All had severe cuff tear arthropathy (Hamada stage 3 or 4) and severe atrophy or fatty infiltration of the infraspinatus and teres minor on preoperative MRI or CT-scan (Goutallier stage 3 or 4). Preoperative and postoperative functions were assessed by Constant score. Satisfaction was assessed by the Simple Shoulder Test (SST). At follow up, radiographs were examined for radiolucent lines, osteolysis and scapular notching.
Results: The average follow-up after surgery was 33.2 months (range 24 to 60 months). The mean absolute Constant score improved significantly ($P = 10^{-5}$) from 23.7 ± 11.5 preoperatively to 61.1 ± 11.9 postoperatively. Forward flexion and external rotation with the arm at the side improved significantly, respectively from $64.7 \pm 35.6^{\circ}$ preoperatively to $126 \pm 34.4^{\circ}$ postoperatively ($P < 10^{-5}$) and from $-8.7 \pm 21.3^{\circ}$ to $27.3 \pm 12.2^{\circ}$ ($P < 0.0005$). Internal rotation was not

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affected. The mean SST improved from 1.9 ± 1.6 points preoperatively to 7.6 ± 1.8 points postoperatively ($P < 0.0005$). Twelve patients were very satisfied or satisfied (including one with a bilateral procedure) and 2 were unsatisfied with the final result. At final follow-up, radiographs showed no radiolucent lines around the implants nor scapular notching.
Conclusion: The combined procedure helped restoration of active elevation and external rotation in cases of massive cuff tear including the teres minor tendon.
Level of evidence: Therapeutic Level IV.
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Introduction

Reverse shoulder arthroplasty allows restoration of a painlessness active range of elevation in patients with a cuff tear arthropathy. However, it does not improve active external rotation in the setting of a teres minor deficit. In cases of an irreparable posterosuperior cuff tear including the teres minor tendon, highlighted by a dropping sign and an external rotation lag sign [1—4], the reverse arthroplasty can enhance the ability to perform activities of daily living at waist level. However, in some instances, clinical results can be adversely affected by the procedure. Tendinous transfers have been used widely for the treatment of Erb's palsy in the pediatric population by aiding active external rotation [5—9]. In 1934, L'Episcopo [5] described transfers of the teres major tendon by both anterior and posterior approaches. In 1947, Zachary [6] modified this technique for a two-tendon transfer, combining both latissimus dorsi and teres major tendons. In 1949, Merle d'Aubigné [7] described this combined transfer using a single deltopectoral approach. In 2007, Boileau et al. [10] described a combination of both tendons transfer with a reverse shoulder replacement using a single deltopectoral approach. In 2010, they reported, with this combined procedure, an improvement of active elevation and external rotation [11], with a decrease of functional internal rotation however.

We hypothesized that in the rare cases of cuff tear arthropathy with a lesion affecting the teres minor, latissimus dorsi and teres major tendon transfer combined with a reverse prosthesis would improve active external rotation and clinical results. Fixation of transferred tendons to the anterolateral aspect of the humerus, instead of its posterolateral aspect as described previously [10], should allow preservation of preoperative levels of internal rotation and improve external rotation.

Methods

Inclusion and Exclusion Criteria

The criteria for inclusion in this retrospective study were:

- a painful shoulder with a massive irreparable posterosuperior rotator cuff tear;
- a loss of both active elevation (unable to achieve 80 degrees of active forward flexion) and active external rotation (indicated mainly by the presence of a dropping sign (Fig. 1) [1—4]);
- the presence of a functional deltoid muscle;
- objective atrophy of the teres minor muscle as seen on CT-arthrogram;
- fatty infiltration of the infraspinatus graded as at least stage 3 according to the classification of Goutallier et al. [12];
- surgical procedures combining a reverse shoulder arthroplasty with a latissimus dorsi and teres major transfer reviewed with a minimum follow-up of 2 years.

The main exclusion criteria was the ability of the patient to maintain active external shoulder rotation of greater than 10° in 90° of abduction — indicating the presence of a functional teres minor.

Figure 1 Dropping sign.

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Patients

Between February 2006 and April 2009, 15 shoulders in 14 patients (10 women and 4 men) underwent a reverse shoulder arthroplasty combined with a latissimus dorsi and teres major transfer procedure. All of patients had failure of rehabilitation before surgery. All operations were performed by a single shoulder surgeon (PV). The average age of the patients at the time of the operation was 67.5 years (range 53 to 82 years). Nine patients had repairs of their dominant shoulder, nine of which were right sided and six left.

Preoperative anteroposterior (AP), outlet and axillary radiographs were obtained for each patient. On the outlet view (static and dynamic), superior and anterior migration of the humeral head under the coracoacromial arch was seen. Shoulder arthrosis was classified according to the radiographic system of Hamada et al. [13].

A cuff tear arthropathy was noted in 13 cases, with six graded stage 3 and seven graded stage 4A. Last two cases demonstrated avascular necrosis of the humeral head.

Muscle atrophy and fatty infiltration levels of the rotator cuff muscles were assessed, for all patients, by arthro CT-scan according to the system of Goutallier et al. [12] and by magnetic resonance imaging (MRI) according to the modified classification defined by Fuchs and Zanetti [14—15]. The fatty infiltration of both infraspinatus and teres minor was graded either stage 3 or 4 in all shoulders.

Surgical technique

Both procedures, reverse shoulder arthroplasty and tendon transfer (latissimus dorsi + teres major), were performed during the same procedure via a single deltopectoral approach.

Surgical approach

The patient was placed in a ''semi-sitting'' beach chair position with the entire upper limb prepared and draped. The arm was left free to facilitate glenoid exposure and tendon harvesting. A standard deltopectoral approach was used, extending distally to the humeral insertion of the deltoid. The incision started from the clavicle to the inferior border of the pectoralis major tendon, following the deltopectoral interval lateral to the coracoid. The cephalic vein was retracted laterally. The musculocutaneous nerve was identified prior to insertion of a retractor under the conjoint tendon. A second retractor was placed under the anterior fibers of the deltoid. The irreparable character of the massive rupture of supraspinatus and infraspinatus was confirmed in extension, abduction and medial rotation. When the long head of the biceps was still present (10 cases), it was consistently found to be pathologic and a tenodesis with local soft tissues was performed in the superior part of the bicipital groove, using an absorbable suture (Vicryl N°2-0; Ethicon®). The intra-articular portion was resected. The anterosuperior fibers of the subscapularis were frayed or partially torn in 10 cases. The anterior circumflex vessels were ligated before performing a vertical incision of the subscapularis at its myotendinous junction, with the arm placed in an external rotation and a forward flexion position. Two non-absorbable stay sutures (Ethibond N°3; Ethicon®) were placed into the subscapularis stump. After capsulotomy, the coraco-acromial and coraco-humeral ligaments were released in order to obtain better gliding of the superior border of the subscapularis tendon under the coracoid process.

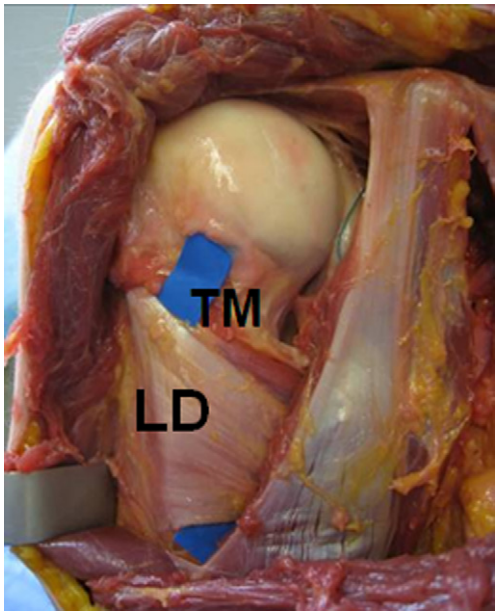

Figure 2 Cadaveric view of latissimus dorsi and teres major tendons.

The pectoralis major was transected 1 cm medial to the humeral insertion, allowing a good exposure of the tendinous portions of latissimus dorsi and teres major (Fig. 2).

Harvesting and preparation of rerouted latissimus dorsi and teres major transfer

Before dissecting the tendons, the axillary nerve was located by digital retraction above the teres major. The latissimus dorsi tendon was consistently identified anterior and inferior to that of teres major at their humeral insertion site. Sometimes, these insertions seemed to form a conjoint unit which could be separated by a sharp dissection. The average lengths of the tendinous portions were 8.4 cm for the latissimus dorsi (range 6.3 to 10.1 cm) and 3.9 cm for the teres major (range 3.3 to 4.6 cm).

Latissimus dorsi and teres major were detached from the humerus with periosteal tissue and non-absorbable stay sutures (Ethibond N°3; Ethicon®) were placed into both tendinous stumps (Fig. 3). When the tendons were fully mobilized, a curved clamp was guided around the surgical neck of the humerus, close to their bony insertions. Thus creating a tunnel of sufficient calibre to allow passage of the tendons using the stay sutures. The tendons were then left on the lateral aspect of the humerus and secured before implanting the reverse shoulder prosthesis.

Reverse shoulder prosthesis implantation

The arrow reverse shoulder prosthesis (FH Orthopedics, Mulhouse, France) was used in all cases. It includes a lateralized center of rotation (8.5 mm) compared to embedded glenospheres.

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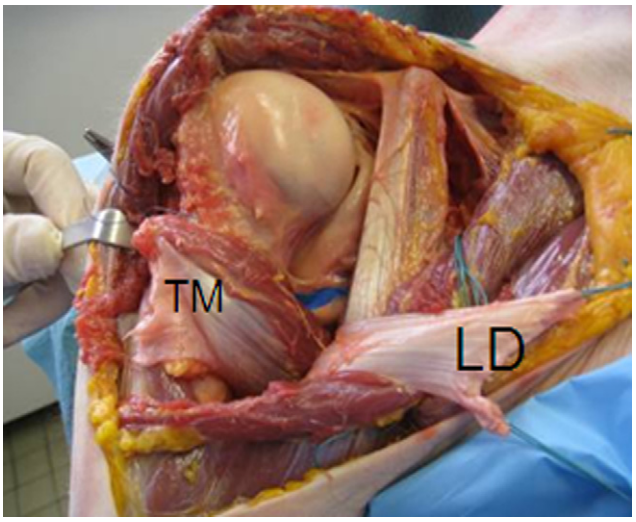

Figure 3 Latissimus dorsi detached with periosteal tissue.

The bony cut of the humeral head was started 5 mm above the junction of the cephalic cartilage and the greater tuberosity with an inclination of 135° and a retroversion of 20°. The metaphysis and epiphysis were prepared with progressively larger graspers, with the aim of conserving as much cancellous bone as possible to allow a press-fit fixation of the humeral stem. Impacting cancellous bone graft from the humeral head in the medial part of the metaphysis conferred excellent primary stability. Cementless fixation was used in 13 cases. Cement was used in two cases with primary stability deemed insufficient using trial components, due to osteoporotic bone.

Preparation of the glenoid was performed after a circumferential capsulectomy. A retractor placed anteriorly facilitated orientation of the glenoid and allowed positioning of the central hole with the stopper drill. Cartilage was removed by a slight reaming, taking into account the very weak subchondral bone in this population, revealing subchondral bone, in order to medialize the glenosphere according to Grammont's et al. concepts [16]. The metal back was positioned at the inferior part of the glenoid, with a slight inferior tilt to avoid a scapular notching [17—18]. A posterosuperior glenoid defect was observed in four cases. All were grafted with cancellous chips from the humeral head to avoid baseplate malposition, particularly superior tilting.

Fixation of the both transferred tendons

The arm was positioned in 30° of abduction and around 30° of external rotation. Both harvested tendons were fixed at the same level. Both stay sutures of the latissimus dorsi tendon were fixed with one bone anchor (Super G4 Mitek; Depuy®) close to the lateral part of the bicipital groove, on the cortical bone, without abrasion. Both stay sutures of the teres major tendon were fixed in a more posterior position (less potential for excursion of this short and bulky muscle) with another bone anchor, without abrasion. The subscapularis was reattached transosseously in the medial aspect of the lesser tuberosity. The Pectoralis major was repaired anatomically. The deltopectoral incision was closed over one drain for 48 hours, and the arm was placed in a special brace with 30° of abduction and 30° of external rotation.

Postoperative management

The brace was applied for 6 weeks. A physiotherapy program was started at 6 weeks with daily pendulum exercises and passive range of motion (ROM) in elevation and external rotation until neutral rotation. Active ROM exercises were performed after 2 months.

Functional and radiological assessment

Preoperative and postoperative functions were assessed by the objective rating scale of Constant and Murley [19].

Preoperative and postoperative ROM's were compared. Active external rotation, internal rotation, and elevation were evaluated by physical exam using a goniometer. The presence of dropping and lag signs were also noted.

Satisfaction was assessed by the simple shoulder test (SST) (12-item questionnaire) [20] and finally by asking the patients if they were very satisfied, satisfied or unhappy with the functional outcome.

At final follow-up, radiographs were examined for radiolucent lines, metaphyseal osteolysis and scapular notching.

Statistical analysis

Measurements are expressed as the mean ± standard deviation. Differences between preoperative and postoperative clinical results were compared using a student's *t*-test. A significant difference was defined as $P < 0.05$.

Results

The average follow-up after surgery was 33.2 months (range 24 to 60 months). There were no patients lost to follow-up. No infection and no anchor-related complications were noted in this series of 15 shoulders. One patient had a transient postoperative high radial palsy with a complete recovery after three months. In one case, the humeral implant appeared dislocated inferiorly at their last review, 48 months after surgery. The lag sign had however disappeared and no axillary nerve deficit was noted in this patient who was maintained in this series. A revision with a thicker polyethylene humeral cup (+5 mm) was suggested to him.

The absolute Constant score improved significantly ($P = 10^{-5}$) from an average of 23.7 ± 11.5 preoperatively to 61.1 ± 11.9 at the latest follow-up. Active forward flexion and active external rotation with the arm at the side improved significantly, respectively from 64.7 ± 35.6° preoperatively to 126 ± 34.4° postoperatively ($P < 10^{-5}$) and from −8.7 ± 21.3° to 27.3 ± 12.2° ($P < 0.0005$).

The mean score for ability of the patients to perform activities of daily living improved significantly from 4.4 ± 1.6 to 11.7 ± 2.8 ($P < 10^{-5}$) at last review. However, the improvement in internal rotation was not statistically significant ranging from 4.4 ± 2.8 to 5.5 ± 1.9 ($P = 0.056$). The SST improved from an average of 1.9 ± 1.6 points preoperatively to 7.6 ± 1.8 points postoperatively ($P < 0.0005$).

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Six patients were very satisfied (including one with a bilateral procedure), six were satisfied and two were unsatisfied with the final result. The unsatisfied patients included the one with the dislocated prosthesis at the most recent follow-up, who is awaiting revision using a thicker polyethylene humeral cup, and another one with a shoulder which remained stiff despite the procedure (forward flexion: 40°, external rotation: 0°, Constant score: 41).

At the most recent follow-up, radiographs showed neither radiolucent lines around the glenosphere nor the humeral implants. No scapular notching was observed with the reverse shoulder prosthesis, which includes a glenosphere with an 8.5 mm lateralized center of rotation and a humeral metaphysis with a 3.5 mm lateralization related to its concept.

Discussion

Cases requiring a reverse shoulder arthroplasty combined with tendon transfers remain rare, representing 10% of our Reverse Shoulder Arthroplasties (RSA) series during the same period (150 RSA performed in total). This combined technique represent a reliable solution in case of a loss of both active anterior elevation and external rotation related to a massive, irreparable posterosuperior cuff tear with or without arthropathy or to cuff denervation [21].

The infraspinatus and the teres minor are the main external rotators of the shoulder, while the deltoid has no contribution in the axial rotation ROM in non-implanted and in implanted shoulders [22—23]. Therefore, in case of pseudoparesis with atrophy of both infraspinatus and teres minor muscles, highlighted clinically by the presence of a dropping sign [1—4], a single reverse shoulder prosthesis can restore forward elevation and abduction through the action of the deltoid but the recovery of active external rotation remains a significant functional problem [24—26]. Simovitch et al. [27] have shown that functional results of reverse total shoulder arthroplasty were inferior in the presence of fatty infiltration of the teres minor.

The results of the current study and those of previous studies [10—11,28—29] show that a reverse prosthesis combined with a muscular transfer, such as the modified L'Episcopo, allows simultaneous treatment of the external rotation and forward elevation deficits and improves clinical outcome. Costouros et al. [30] did not observe a statistical improvement of the active external rotation in case of complete atrophy of the teres minor (fatty infiltration greater than stage 2) after latissimus dorsi tendon transfer for irreparable rotator cuff tears. The gain of external rotation in this series may thus be attributed to the transfer of the teres major.

The weaknesses of this study are the limited number of patients included, its retrospective nature, the absence of a control group and the overall short-term follow-up (33.2 months, range 24 to 72 months).

In this series of 15 shoulders operated during a 3.2-year period by single shoulder surgeon (PV), all the criteria of the Constant's score improved significantly, except the internal rotation active ROM. We conclude that this procedure significantly improved external rotation without affecting internal rotation. However, in absence of a control group, the contribution of the tendons transfer in the final result, especially in the external rotation improvement, cannot be evaluated precisely in comparison with the contribution of the prosthesis, and particularly with its concept. Boileau et al. [11], in a series of 17 consecutive patients, found significant improvements in active elevation, external rotation, Constant-Murley score, activities of daily living requiring external rotation (ADLER) score [28], and subjective shoulder value (SSV). However, functional internal rotation decreased from a mean Constant-Murley value of 6 to 2.

For Brumback et al. [31] and for Laitung et al. [32], by transferring the latissimus dorsi, the loss of its contribution in internal rotation does not explain the functional loss. For Gerber et al. [33], the postoperative subscapularis insufficiency can explain the loss of internal rotation often encountered and this represents one of the main limitations of a latissimus dorsi tendon transfer.

The loss of internal rotation reported by Boileau et al. [28] that was not seen in this study despite a similar approach may be explained by the fixation of the harvested tendons at the pectoralis major stump using tendon-to-tendon sutures. In our study the tendons were only fixed with anchors, near to the lateral aspect of the bicipital groove for latissimus dorsi and more posteriorly for teres major (due to its shorter excursion), allowing preservation of preoperative internal rotation but without significant improvement either.

Moreover, external rotation improved significantly by a mean of 36°, from −8.7° preoperatively to 27.3° postoperatively ($P < 0.0005$). For Boileau et al. [11], the improvement in external rotation was similar, with a gain of 34° at mean, going from −21° to 13°. The better absolute value of postoperative active external rotation in the present study can be related to a different method of fixation of the harvested tendons, near to the bicipital groove at the anterolateral aspect of the humerus instead of the posterolateral aspect of the humerus as performed by Boileau et al. [11]. Fixation of the transferred tendons to the anterolateral aspect of the humerus without tendon-to-tendon sutures at the pectoralis major stump allowed preservation of preoperative levels of internal rotation and improved external rotation.

Gerber et al. [29], in a series of 10 similar combined procedures with an average follow-up of 18 months, fixed their tendons at the posteroinferior aspect of the greater tuberosity, at the insertion site of the teres minor. They found significant improvements in SST, absolute and relative Constant scores, scores for activities of daily living and pain, strength and working capacity. However, improvement in active external rotation with the arm at the side of the body (from 12° to 19°) was not significant. Favre et al. [23] have shown, in a biomechanical study, that with a distal insertion site, the inferior transfer is less displaced from the axis of rotation and has a diminished mechanical advantage in external rotation.

Furthermore, contrary to our technique and those of Boileau et al. [11,28] using a single deltopectoral approach to perform both the reverse prosthesis implant and the tendons transfer, Gerber et al. [29] used a second incision laterally to the posterior axillary crease to harvest the tendons. They did not report any complication related directly to this 2-incision technique, but many other series

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of isolated L'Episcopo transfer [34—35] reported extensive scarring and adhesions, as well as transient or permanent axillary nerve dysfunction.

Conclusion

This study shows that a reverse shoulder arthroplasty combined with a latissimus dorsi and teres major tendon transfer allows the improvement of elevation and external rotation in cases of massive, irreparable posterosuperior cuff tears in addition to teres minor tendon lesions. A precise technique with a fixation of both latissimus dorsi and teres major tendons to the proximal anterolateral aspect of the humeral head without tendon-to-tendon sutures at the pectoralis major stump significantly improved external rotation without affecting internal rotation. A longer-term follow-up of our present series and more of such cases in the future would provide further confirmation of these favourable results.

Disclosure of interest

One of the authors is consultant for Fournitures Hospitalières Industrie (Mulhouse, France) and has received royalties for a product related to this work.

None financial remuneration related directly or indirectly to the subject of the article have been received by the two other authors (OB, AK) or by any member of their family.

These two other authors certify that they have no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

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