Annals of Medicine and Surgery 71 (2021) 103010

Contents lists available at ScienceDirect

Annals of Medicine and Surgery

journal homepage: www.elsevier.com/locate/amsu

Case Report

Anatomic based microfracture technique of insertion for rotator cuff repair in Vietnamese people: Case series study

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ARTICLE INFO

Keywords:
Rotator cuff tear
Microfracture
Tendon healing
Anatomy
Case series

ABSTRACT

Abstract: Postoperative tendon healing is still a matter of concern after rotator cuff repair. Several techniques have been introduced to help improve this healing process. Among them, the bone marrow is commonly used source and a research subject for methods using stem cells to promote wound healing process. A number of studies have shown that bone marrow stem cells can travel up through the holes on the rotator cuff insertion sites, contributing into the rotator cuff repair process, increasing the efficiency of tendon healing and improving clinical results.

Patients and methods: Cross-sectional descriptive study was performed on 41 rotator cuff tear patients. The microfractures for these patients were calculated beforehand, which have great depth but small diameter, based on the anatomical characteristic of the rotator cuff tear insertions of Vietnamese people. Patients' rotator cuff tendon healing processes were evaluated using ultrasound after surgery. Final tendon healing and clinical results ultimately rely on MRI assessments, classified according to Sugaya's classification, UCLA and ASES scale.

Results: No cases of rupture and fracture of the greater tubercle was recorded. There was a clear progression of tendon healing on ultrasound according to postoperative follow-up time-stamps (1 month, 3 months). MRI images evaluation also reveals at the latest follow-up time, according to Sugaya classification, the ratio of tendon healing was 87.8%, while the percentage of re-rupture was 12.2%. ASES and average UCLA scale were collected at the end of the study, respectively as 95.41 $\pm$ 5.45 and 32.36 $\pm$ 2.53.

Conclusion: The technique's microfractures characteristics based on the rotator cuff tear insertion anatomy ensures a secure, straightforward approach along with promising results in terms of tendon healing rate and postoperative functional outcomes.

1. Introduction

The effectiveness of rotator cuff (RC) repair surgery is increasing with clinically significant improvements.[1] However, it is undeniable that the problem of re-rupture of the rotator cuff tendon after surgery still exists and is recognized by the authors with variable rates from 4% to 94% [1–4].

Some authors have studied extensively on factors related to the increased proportion of post-operative tendon healing and noticed poor quality of bone tissue and tendons may affect the RC tendon-to-bone healing process, which is believed to be the primary cause of tendon failure or re-tearing [5–7]. Present techniques of increasing blood flow to RC insertion sites such as grinding bone surface fail to provide adequate resources and optimal blood vessels for the repair process. There are four main sources of mesenchymal stem cells that have been proven to promote tendon healing in cell therapy: bone marrow, fat, tendon, and synovial tissue [8]. Of which bone marrow is a widely used source and also the most popular research subjects for stem cells methods to promote wound healing process. Many recent studies have displayed that extraction from humerus [9–11] as well as the use of bone marrow stimulation techniques are viable options for obtaining bone marrow stem cells in a clinical setting [12–15]. In most of these studies, the authors used conventional endoscopic awls to create microfractures, which are instruments with a tapered tip at the end, gradually enlarged

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https://doi.org/10.1016/j.amsu.2021.103010
Received 4 October 2021; Received in revised form 29 October 2021; Accepted 31 October 2021
Available online 6 November 2021

at the top, which will lead to limitations in terms of quantity, depth and spacing consistency. Deriaving from these problems, we proceed to create microfractures based on anatomical features of rotator cuff insertions characteristics with the purpose of ensuring that the microfractures of the anchoring site are consistent with the area of the rotator cuff insertion sites. These microfractures was created with greater depth and smaller diameter than the previous techniques and using navigational aids to ensure uniformity. These patients were then assessed in terms of effectiveness of the technique based on tendon healing and clinical results. This article has been reported in line with the PROCESS 2020 criteria [20].

2. Patients and methods

We conducted a Cross-sectional descriptive study on a group of 41 patients with confirmed diagnosis of rotator cuff tear (RCT), and was subjected to RC tendon surgery. All patients underwent the same surgical method (RC tendon suture using endoscopic technique of Mason-Allen tendon suture modified), in combination with creating microfractures at the insertion sites, during the procedure.

2.1. Microfractures creating method

- Microfractures positioning: Due to the one-row stitching technique, with the location of the anchor at the outer edge of the insertions site, we based our method on the distances from the outer edge of the RC insertions which is from the anterior border of the tendon on the supraspinatus, infraspinatus, teres minor (points B, G, K, Fig. 1) to the articular cartilage edge (mean value of 10.01-10.25-12.8mm respectively), which is collected from our study of anatomical indicators of the rotator cuff enthesis on 20 Vietnamese cadavers to serve as calculation basis for the location of microfractures. With the average distance measured, we proceed to create microfractures inside the anchoring sites in the formation of 2 rows with the first row at the edge of cartilage, and 2nd row 5mm laterally apart compared to the first row and the microfracture positions intertwined with the first row (see Fig. 2).

- Microfractures characteristics: We tend to create small and deep microfractures. Using Kischner nail with the diameter of approximately 1,4 mm and marked guidelines, we created microfractures on the insertion position, of which these holes have a depth of approximately 10 mm.
- Use of assisting tool to create microfractures: In order to confidently facilitate and ensure accuracy for the procedure, we manufactured this tool to help create fractures, with a structure resembling a compass. This tool consists of a fixed part (compass foot) that is fixed to a hollow tube 1.5 mm in diameter. The distance between the center of the hollow tube and the compass foot is 5mm. After that, the microfracture creating instrument will then pass through this hollow tube, having a 10 mm length marked starting from the tip. Thanks to this tool, the distance between the microfractures will be ensured to share the consistency in terms of size and depth.
- Proceed to stitch the RC tendon and tie the suture knots. After which, all of the area besides the knots and RC tendon are exposed to perform additional microfractures on (Fig. 3).

2.2. Data collection

- Tear classification of injuries according to DeOrio and Cofield RH [16]. Evaluation of the final tendon healing based on MRI according to the degree of tear based on Sugaya 's classification [17] (at the end of the study >06 months).
- Patients' tendon healing process were closely monitored using ultrasound, evaluated clinically after surgery at the follow-up time of 1 month, 3 months, and finally, before the end of the study.
- Postoperative clinical outcomes were evaluated based on the UCLA, ASES scale [18,19](at the end of the study).
- This case series has been reported in line with the PROCESS Guideline [20].

3. Results

- Intraoperative tear classification according to DeOrio and Cofield RH [16].

We notice that medium and large tear contributed of most proportion (73.2%), with massive tear having the least proportion (7.3%).

- No cases of broken bones in the process of creating microfractures and tendon sutures anchoring
- Postoperative ultrasound evaluation at 1 month and 3 months after surgery has seen a significant improvement: Lowered average tendon thickness (5. 8 ± 1.6 and 5.3 ± 1.8 mm) and increased tendon echogenicity near the enthesis
- Perform MRI tests to evaluate postoperative tendon healing outcomes after 6 months or above, based on the classification of Sugaya[17]

It is noticeable that grade 1 and grade 2 tendons have the highest rate 78%

- Assessment of the relationship between the tendon tear and postoperative tendon healing

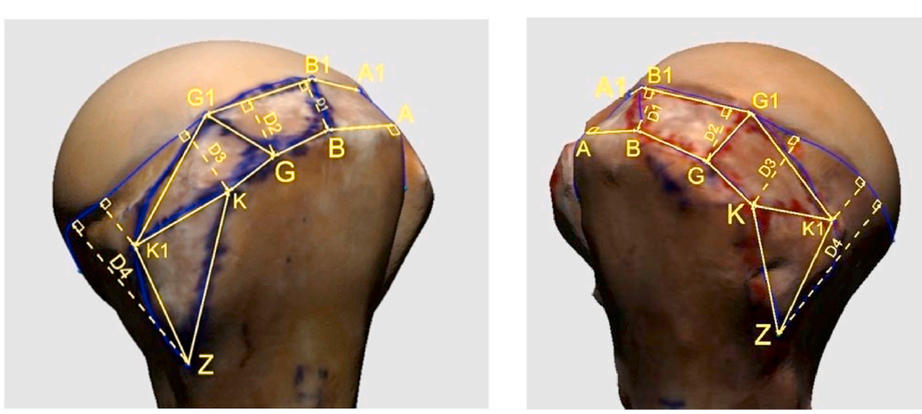

Fig. 1. Illustration of the rotator cuff insertion sites and anatomical landmarks on the lateral border of the rotator cuff tendon measured on a cadaver (these points are determined by following the boundaries between the supraspinatus, infraspinatus, teres minor tendons and the outer border of the insertion on the greater tubercles: B, G, K).

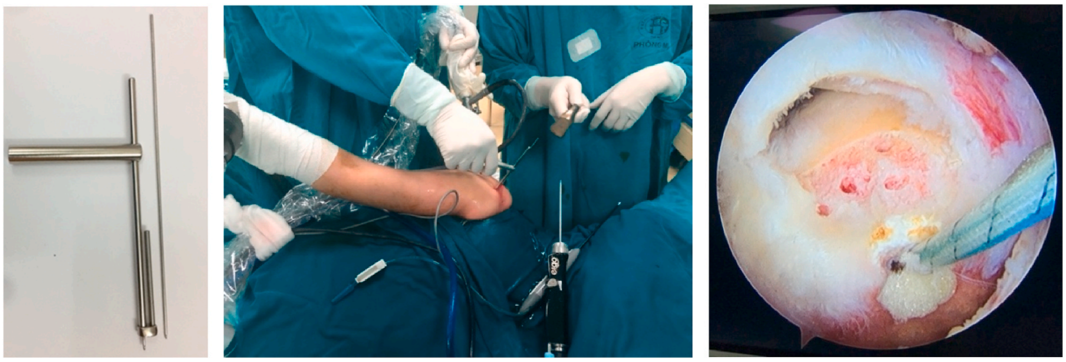

Fig. 2. Use of tools to create microfractures on insertion sites.

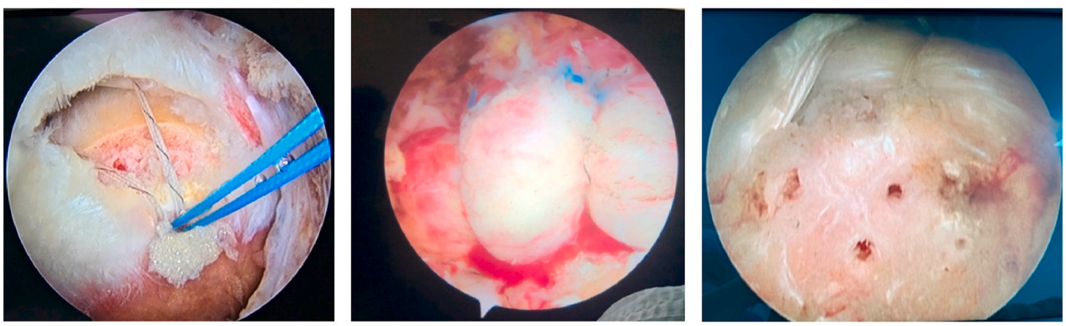

Fig. 3. Creating additional microfractures after tying RC sutures.

Based on the above table, small and moderate tears have excellent results on post-examination MRI, with no cases of re-tearing have been recorded. There are 3 patients in the large tear group and 2 patients of massive tear group suffered from re-tear of the RC tendon. 4 patients (of which 1 patient had a massive tear of the rotator cuff tendon which could not be sutured in the surgery) reported symptoms of re-tear in the first 3 months after surgery. Another case was torn again by a fall after 5 months.

- We used ASES and UCLA scale to assess shoulder function after surgery

The average ASES score after surgery was 95.41, clearly improved compared to before the surgery. The patient has lowest ASES score of 76.67 and the patient with the highest ASES score of 100, some patients were able to confidently return to playing tennis, pull-ups and weight training, carrying grandchildren and heavy objects as opposed to before the surgery.

The average postoperative UCLA score is 32.36 ± 2.53 which is classified as good.

Based on the chart above, it shows that ASES score and tedon healing degree have a positive correlation (Chart 1), the highest ASES score is with type I tendon group and the lowest with type V tendon group. The difference is statistically significant with $p = 0.01 < 0.05$.

4. Discussion

In 2009, two authors Snyder and Burns [21] first reported a simple technique of “bone perforation” to create bone marrow holes for the purpose of creating a “Crimson Duvet-dark red blanket” covering about 2–3cm above the greater tubercle of the humerus from the articular edge in patients undergoing arthroscopic RCT surgery. The development and maturation of this "blanket" was evaluated using MRI at 4 weeks, 6 weeks, and 8 weeks after surgery, which displayed soft tissue growth at the enthesis. By incidentally re-evaluating endoscopically of one patient at week 2, it was noted that the exposed area, which has artificial bone marrow holes, was covered by a "blanket" rich in blood vessels and tendons as if it had covered all the torn tendons and sutures, through revaluation in the 8th week of another patients that they have found these stoma bone marrows contained the fibrous tissue core layers connected to the "blanket" rich in blood vessels on top. Afterwards, in 2011 and 2013, Jo [13,14] and colleagues reported 2 consecutive studies on the method of creating multiple holes into the greater trochanter to generate bone marrow cell sources, providing a significantly lower re-fracture rate compared to the double-row suture technique, however, the difference was not clinically significant. To evaluate the effectiveness of the technique in comparison with the control group, author Milano et al. [22] randomly divided 80 RCT patients into two groups with the same RC repair techniques, while one group was performed microfractures in the great trochanter on, the other was not. Although the authors found no difference between the two groups, after classifying patients according to the size of damage, they found that the group with microfractures resulted a better tendon healing rate in patients with a great RC tear. Author P.Ajrawat [23] et al., in their meta-analysis of assessments based on data from MEDLINE, Embase, PubMed, Cochrane Central Register of Controlled Trials, and www.clinicaltrials.gov also showed the use Microfractures technique which reduces the rate of re-rupture after surgery.

Based on the research results of the previously published authors, it is the basis for us to conduct microfractures technique and evaluate them on our patient group. Some authors have recommended different approaches to create microfractures at the insertion site, yet these approaches were not particularly meticulous on this procedure. The argument of microfractures is to create holes from the bone marrow so that mesenchymal stem cells can go up through these bone marrow holes, participating in the process of tendon healing. The greater the contact area of the microfractures with the cancellous bone of the humerus, the greater the involvement of bone marrow stem cells. The thickness of the compact bone at the top of humerus is about $4.4 \pm 1{,}0$mm [24]. Typically the authors create microfractures with the assistant of an endoscopic awl, which has a tapered tip at the end with about 5mm depth marked, since this depth is sufficient through the bones. In order to increase the contact area of the of the microfractures with the bone marrow, it must be more deep, however, because the diameter of the commonly used microfracture instruments increases as they go higher, there is a risk of rupture if they increase the depth and the number of microfractures. Therefore we actively create holes with a smaller diameter and greater depth, which not only can reduce the risk of broken bones but also still increase the contact area between the microfractures and bone marrow. Based on several studies on sheeps, Eldracher [25] et al. also proved that creating deeper and smaller microfractures has a better effect than large diameter microfractures.

The risk of fracture should be reduced further based on our research of anatomical indicator on RC insertions, which serve as the foundation to calculate the microfractures position, in order to ensure reliability on the position of these microfractures, in turn, will optimize the effectiveness of microfractures will be optimized. The use of a support system in locating the microfractures will ensure the consistency of distance between the microfractures and the desired depth.

According to Sugaya [17] classification on RC tendon healing, based on MRI assessment at the end of our study (Tables 1-3): Number of patients with a healed tendon (type I, II, III) takes up the majority: 36 patients (87.8%). The number of patients with non-healing tendons (type IV, V) was only 5 patients (12.2%). Therefore, our rate of non-healing tendon is lower than the overall rotator cuff tendon re-tear after surgery which was 20.7% [26]. In several studies on traditional rotator cuff tendon suture, for example, by Cho and Rhee [27] on 169 shoulder joints with arthroscopic suture of the RC tendon, shows the rate of general tendon healing is 131/169 cases (77.5%) in which: the healing rate of the small tear group was 96.7%, the tendon healing rate of the moderate tear group was 87.3% and the large and massive tear group was 58.8%. The probabily of re-tear of the traditional bridging method with or without suture row knot from the study of author Kim [28] et al., is respectively 16.3% and 29.2%. However if the evaluation is based just on the massive and large tear group, the probality of re-tear is only 31.3% (5/16), which is lesser than the rate of re-tearing in massive and large tear group by a number of other authors [26,27,29]. Author Saccomanno [30] et al. also remarked postoperative RC tendon healing is particularly a prominent issue for large and massive tear group.

To accurately assess the progress of tendon healing, authors Snyder and Burns [21] relied on magnetic resonance imaging at 4 weeks, 6 weeks, and 8 weeks, but this is an expensive means of assessment and consent of the patient is required. For convenience and cost reduction in assessing this progress, we use ultrasound in the timeline corresponds with the time of examination to 1 month and 3 months after surgery to understand the first steps of tendon healing after surgery (Fig. 4). Comparing the results of ultrasound was a testament to progress in a positive direction of microfractures by reduction of swelling and increase of tendon echogenicity after surgery respectively at follow-up time at the insertion sites. When compared to the ultrasound data of patients previously received rotator cuff tendon surgical suture but not the microfractures, no major difference after 1 month has been noticed. However, after 3 months, the patients who received microfractures appear to developed a higher rate of tendon echogenicity. Several studies have evaluated rotator cuff tendon ultrasound after surgery 4–6 weeks showed that there is a deficiency of collagen organization of the

Table 1
Tear classification.

Tear classification	n	Ratio (%)
Massive tear	3	7.3
Large tear	13	31.7
Medium tear	17	41.5
Small tear	8	19.5
Total	**41**	**100**

Table 2
Post-operative MRI classification.

MRI classification	N	Ratio (%)
Type I	23	56.1
Type II	9	21.9
Type III	4	9.8
Type IV	2	4.9
Type V	3	7.3
Total	**41**	**100**

Table 3
Relationship between tendon healing on postoperative MRI and degree of tear.

	Massive tear	Large tear	Medium tear	Small tear	Total	p
Type I	1 (4.4)	3 (13.0)	13 (56.5)	6 (26.1)	23 (100)	**0.03**
Type II	0	5 (55.6)	2 (22.2)	2 (22.2)	9 (100)	
Type III	0	2 (50.0)	2 (50.0)	0	4 (100)	
Type IV	1 (50.0)	1 (50.0)	0	0	2 (100)	
Type V	1 (33.3)	2 (66.7)	0	0	3 (100)	
Total	**3 (7.3)**	**13 (31.7)**	**17 (41.5)**	**8 (19.5)**	**41 (100)**	

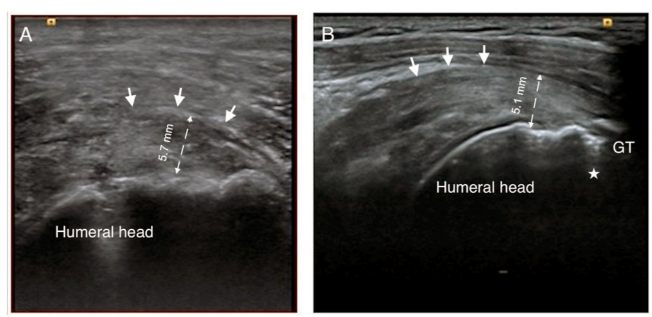

Fig. 4. Ultrasound evaluation at 1 month and 3 months after surgery. Picture A on the left is 5.7mm thick at 1 month, picture B on the right is 5.1mm thick.

enthesis and an uneven edema between tendon collagen bundles and neovascularization at the insertion sites [31,32]. It is possible that the microfractures will help facilitate the growth of new blood vessels from the bone marrow, so that the soft tissues and the hyperechoic signal at the insertion sites will gradually increase. This is a prominent sign of an ultrasound-based evaluation of tendon healing. Author Yoo and colleagues also mentioned the usefulness of ultrasound in assessment the rotator cuff tendon healing progression after surgery [33]. However, the question remains is why is ultrasound rarely used to evaluate the final results of tendon healing after surgery? Author Kruse [34] examined in his research shows the primary reasons for the members of the American Shoulder and Elbow Surgeons not using ultrasound in the diagnosis of preoperative RCT because of lack of confidence in determining the recovery ability of the torn tendon after surgery in terms of fat infiltration, muscle atrophy and degree of inward retraction compared with acromial, that is, in addition to assessing tendon healing, the evaluation of the quality of tendon after surgery is limited.

With an average follow-up time of 17.51 months, of which the shortest was 11.3 months, the longest was 24.07 months until the end of the study. Mean ASES score and UCLA score at the end of the study were 95.41 ± 5.45 and 32.36 ± 2.53 (Tables 4 and 5, Chart 1) may reflects a promising result of our compared with the results of a number of authors and our other patients who did not received the microfractures technique. Based on the results of tendon healing, the postoperative ASES score and the correlation between the postoperative score and the

Table 4
ASES score before – after surgery.

Average ASES Score	Mean ± SD	Min-max	p
ASES before surgery	30.05 ± 12.26	8.33–7 0	<0.01
ASES after surgery	95.41 ± 5.45	76.67–100	

Table 5
UCLA scale results.

Average UCLA	Mean ± SD	Min-max
UCLA	32.36 ± 2.53	27–35

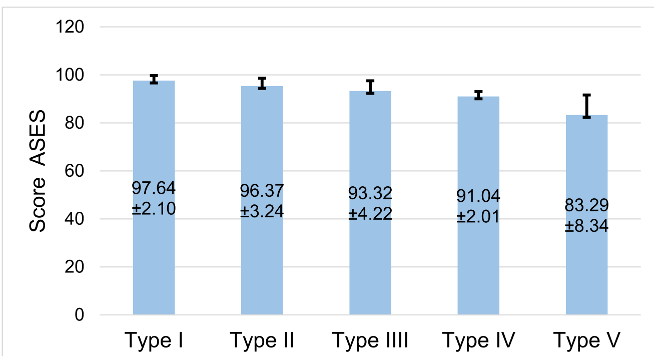

Chart 1. Relationship between postoperative ASES score and tendon healing degree (n = 41).

degree of tendon healing, we found that there is a proportional correlation between the degree of tendon healing and the clinical evaluation score. The obtained results could be higher functionality explained by the effectiveness of microfractures at the insertion sites, which may have reduced the rate of re-torn tendon and increase our tendon healing rate.

Several studies have shown a correlation between clinical outcome and RC integrity on postoperative MRI. RC integrity is an important factor in patient outcomes, such as better shoulder function and better pain relief [4,30]. The author Giuseppe Fama [35] et al. in the evaluation of surgical results RC partial stitching with microfractures at the insertion sites also showed great clinical and functional results, with better restored muscle power, higher satisfaction, pain reduction.

5. Conclusion

Our study evaluated 41 patients who underwent RCT surgical suture with the combination of microfractures with a smaller diameter and greater depth at RC insertions sites with an average postoperative follow-up time of 17.51 months when the result of tendon healing is noticeable after surgery. There were no cases of broken or ruptured bones on the greater tubercle. The rate of joint healing after surgery is high, especially in the small and medium tear group, where 100% of cases of re-tear are not recorded after surgery and the ASES score after surgery is higher than before surgery. This is a straightforward, low-cost technique which can be applied during surgery.

Ethical approval

This study, involving human subjects and human data, has been performed in accordance with the Declaration of Helsinki and has been approved by the Ethics Committee at the Hanoi Medical University, Hanoi, Vietnam, in March 2017. Further information and documentation to support this is available to the Editor on request.

Sources of funding

NA.

Author contribution

The idea for the manuscript was conceived in Feb 2017 by TDD and was further developed by DTT; MNH, DTT, MNH and QT wrote the 1st draft of the manuscript. TDD, MNH and QT have been involved in surgery and data collection, whereas QT and VVD performed the statistical analysis. TDD, MNH reviewed the manuscript and were involved in its critical revision before submission. All authors have read and approved the nal manuscript.

Consent

Written informed consent was obtained from the patients alive at the moment of the study for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal on request.

Research registration

https://www.researchregistry.com/register-now#home/?view_2_search=researchregistry7210&view_2_page=1.

Guarantor

Professor Dung Tran Trung MD, PhD

CRediT authorship contribution statement

Dung Tran Trung: the main doctor conceived the original idea and operated the patients, revised manuscript

Manh Nguyen Huu: followed up, operated the patients, revised manuscript

Quyet Tran: followed up, summed up, revised manuscript

Viet Vu Duc: followed up, wrote manuscript

Disclaimer

The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Declaration of competing interest

The authors of the manuscript have no conflicts of interest.

Acknowledgements

NA.

Provenance and peer review Not commissioned, externally peer-reviewed.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2021.103010.

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