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Research Article

Structural auto- and allograft glenoid bone grafting in reverse shoulder arthroplasty - Retrospective radiological analysis of 38 cases

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ABSTRACT

Background: A structural glenoid bone graft may be utilized in conjuction with reverse shoulder arthroplasty (RSA) in order to address native bone deficiency and/or lateralize the glenoid. The longevity of this type of construct is of potential concern especially with allograft bone grafting. We wanted to study the radiographic construct survival in primary and revision RSA with structural glenoid auto- and allograft bone grafting.
Methods: We retrospectively identified all patients who had undergone RSA, with an encompassing structural bone graft under the metaglene bearing at Turku University Hospital between 2014 and 2019. All patients were called for follow-up and evaluated radiographically and clinically. Shoulders were divided into auto- and allograft groups and radiographic bone graft incorporation and component survival were used as primary outcome measures and between group differences were statistically analyzed.
Results: There were 38 shoulders/34 patients (out of 56) with a mean follow-up of 34 months. The mean age of patients at time of surgery was 69 years (SD 11). 26 auto- and 12 allografts were used at index surgery. At follow-up the bone graft was fully incorporated, partially incorporated and fully resorbed in 44 %, 50 % and 6 % of cases respectively. There was no statistically significant difference in bone graft incorporation between the groups and none of the prosthesis components showed radiographic signs of loosening.
Conclusions: Glenoid bone grafting in conjunction with RSA is a safe and reliable method to restore the glenoid bone stock and secure the construct in short term follow-up. There may be no significant difference in component survival between auto- and allograft bone grafting techniques. Longer-term follow-up is needed to assess the final outcome with regard to these techniques.
Level of evidence: Level IV; Case series, Treatment Study.

1. Introduction

A structural glenoid bone graft may be utilized in conjunction with primary and revision reverse shoulder arthroplasty (RSA) in order to address bony medialization, resorption, dysplasia or fracture, and to provide mechanical support for the glenoid component bearing against the native bone.[1–8] The rationale for glenoid bone grafting is to align and restore muscular tension and joint stability, and to provide mechanical fixation stability.[9] Lateralization by glenoid bone grafting may also increase impingement free range of motion (ROM) of the RSA construct.[10,11]

In the last decades both auto- (ATg) and allogenic (ALg) bone grafts have been frequently used, with good short term clinical results also in RSA.[2,4] Nevertheless, also high rates of up to 25 % graft resorption and component failure have been reported in structural glenoid bone grafting.[7] Furthermore, there may be a difference between ATg and ALg construct survivals,[12,13] and therefore the longevity of different structural bone grafts in RSA is of potential concern.

We performed an institution based retrospective study of patients with a structural ATg or ALg glenoid bone grafts in conjunction with primary or revision RSA. Our hypothesis was that the radiographic component survival would be satisfactory, but with a difference between patients with structural ATg and ALg glenoid bone graft RSAs.

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2. Materials and methods

Approval from the department of Orthopaedics and Traumatology at BLINDED HOSPITAL, was obtained to conduct this study. We identified all patients who had undergone RSA, with an encompassing structural ATg or ALg glenoid bone graft under the metaglene bearing, from our operative database from January 2014 to December 2019. Consecutive patients operated with primary or revision RSA for cuff tear arthropathy (CTA), osteoarthritis (OA), inflammatory arthritis, and instability with a minimum 1-year follow-up were included in the study. The flow chart of the study is presented in Fig. 1.

2.1. Operative procedure

The patients were operated by 9 experienced shoulder surgeons with four different RSA prosthesis designs: Delta Xtend (DePuy Synthes, Warsaw, IN, USA), Aequalis Reversed II (Wright Medical-Tornier Group, Memphis, TN, USA), Ascend Flex reverse (Wright Medical-Tornier Group, Memphis, TN, USA), and Trabecular Metal™ reverse (Zimmer Biomet, Warsaw, IN, USA).

Two different operative techniques were used for glenoid bone grafting, and in these techniques either a ATg humeral head or ALg fresh frozen femoral head bone graft was used. In the non-cortical bone graft technique a cylindrical shaped (symmetric or asymmetric) bone graft was harvested either from humeral or femoral head with a specific BIO-RSA barrel-reamer and saw.[10] In the cortical bone graft technique a unicortical dome shaped bone graft was harvested either from humeral or femoral head 5]. The native glenoid was sparingly prepared and freshened to match and fit the bone graft surface, and the metaglene component was fixed through the graft with a long central peg extending at least 1cm into the native glenoid vault. Two locking screws were used to secure the fixation. Type of implant, bone grafting type and technique, glenosphere size, humeral offset and fixation were chosen according to surgeon preference. The subscapularis was always re-attached onto the tuberculum minus if possible.

Postoperatively the arm was immobilized in a sling for three weeks. Passive ROM exercises were then commenced followed by active training after six weeks.

2.2. Clinical data collection

Preoperative data regarding gender, age, operative side, smoking, BMI and prior operations, were recorded together with operative data on diagnosis, prosthesis design and central peg length, and bone graft type. For the purpose of this study patients were called for a follow-up, and pain-VAS, Constant score (CS), Western Ontario Osteoarthritis of the Shoulder (WOOS) index and operation related complications were recorded.

2.3. Radiographic data collection

Preoperative radiographs and computed tomography (CT), and postoperative and follow-up radiographs (true AP and axillary views) were analyzed by an experienced shoulder surgeon, first author of the manuscrpit and a musculoskeletal radiologist, second author of the manuscript. The following parameters were measured and recorded from preoperative images: Hamada classification,[14] glenoid defect according to Walch and Favard[15,16] degrees of glenoid retroversion, and

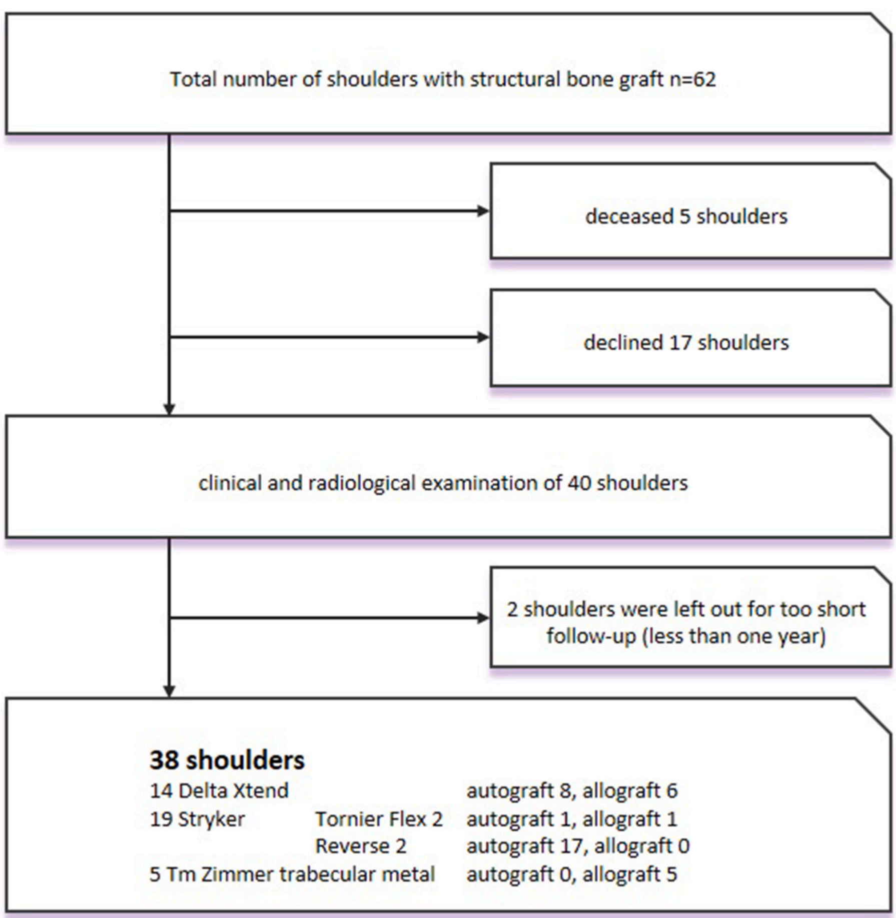

Fig. 1. Flowchart of the study patients.

critical shoulder angle (CSA).[17] Follow-up images were analyzed for: CSA, length of the metaglene central peg in the native bone, bonegraft incorporation (bone incorporated, partially incorporated and fully resorbed), radiographic lucency around the metaglene construct (no lucency, partial lucency, component loose), scapular notching according to Sirveaux,[15] humeral component loosening (no lucency, partial lucency, component loose), and presence of acromion fracture (no fracture, fracture).

2.4. Statistical analysis

The continuous variables in the data are described using means and standard deviations (SD) for normally distributed and accompanied by medians if non-normally distributed. The normality of the empirical distributions was tested using Kolmogorov-Smirnov test. Discrete variables are presented using observed frequencies and proportions using the available observations as the denominator.

The baseline variables of sex, age, BMI, smoking status, type of surgery (primary/revision), diagnosis, Hamada classification, Walch and Favard defect classification, glenoid retroversion and pre-operative CSA were analyzed using Student's t-test if normally distributed and Wilcoxon rank-sum test with continuity correction if non-normally distributed. Clinical background variables of WOOS, VAS and Constant score, and follow-up measures of follow-up time, CSA, Sirveaux classification, incorporation of bone graft, and lucency around metaglene central peg were analyzed similarly.

The main outcomes of bone incorporation, and lucency around metaglene central peg were analyzed with analysis of covariance (ANCOVA) if continuous response. In case of categorical response, multinomial logistic regression model was fitted using the highest or most desirable value as reference class. Both analysis setups were adjusted for follow-up time and type of graft (auto-/allo-) and fitted for each background variable individually. Type III F test was calculated for the overall effects in the model for justification to continue to pairwise comparisons. Background variables that were used in the modeling were height, weight, BMI, dominant side, sex, smoking status, operated side, diagnosis, surgery type (primary/revision), previous procedure, reverse design and age at time of surgery.

All analyses were performed using R version 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria).

3. Results

A total of 38 shoulders (34 patients) out of 62 (56 patients) were available for clinical and radiological follow-up (drop-out rate 39 %) at a mean 34 months (SD 21; range 12–89) postoperatively. There were 25 women (74 %) and 9 men (26 %) and their mean age at time of the operation was 69 years (SD 11; range 45–85). There were 14 Delta Xtend, 17 Aequalis Reversed II, 2 Tornier Flex reverse, and 5 Trabecular Metal™ reverse prosthesis. The mean length of the metaglene central peg was 26.8 mm (SD 2.4). Only centric glenosphere designs were used with 26 ATg and 12 ALg bone grafts. There were 11 index revision and 27 index primary RSA operations, and there was a statistically significantly more index revisions in the ALg group ($p < 0.0001$). Patient demographics in groups ATg and ALg are presented in Table 1. Radiological images are presented in Fig. 2.

The most frequently occurring preoperative Hamada class was 4 (range 1–5) and the glenoid defect A2 and E1 according to Walch and Favard, respectively. The mean degree of glenoid retroversion was 18 (SD 15) and the mean CSA was 31 (SD 8). The bone defects were statistically significantly greater in the ALg group according to both Walch and Favard ($p = 0.04$ and $p = 0.01$, respectively). The preoperative imaging data in groups ATg and ALg is presented in Table 2.

The mean CSA at follow-up was 27 months (SD 12). The central peg of the metaglene component was fixed in the native glenoid in mean depth of 17,4 mm (SD 4; range 9–26). The bonegraft was fully incorporated, partially incorporated and fully resorbed in 16 (44 %), 18 (50 %), 2 (6 %) cases respectively. In 2 cases radiographic incorporation could not be evaluated. There was neither radiographically lucency around the metaglene construct nor humeral component loosening in either group. Scapular notching was present in 11 cases (30 %). At follow-up there was one case with a radiographically detectable acromion fracture in the ATg group, and one case with tuberculum majus fracture associated with transient brachial plexus palsy, and one case with instability requiring revision surgery in the ALg group. The pain VAS, CS and WOOS scores were statistically significantly better in the ATg group compared to the ALg group. Follow-up radiographic and clinical data are presented in Table 3.

There was no statistically significant difference in bone graft incorporation between the two groups. There were neither statistically significant correlations between the bone graft incorporation and the studied parameters.

Table 1
Patient demographics.

	ATg (N = 26)	ALg (N = 12)	p
males/females, n (%)	5 (19 %)/21 (81 %)	5 (42 %)/7 (58 %)	0.2347[c]
age, mean (SD) [median]	73 (7.8) 75	60 (10.9) 60	0.0007[a]
un	29.0 (5.41)	27.5 (4.11)	0.3631[b]
smoking, yes/no, n (%)	2 (8 %)/24 (92 %)	1 (8 %)/11 (92 %)	1.0000[c]
primary/revision, n (%)	26 (100 %)/0	1 (8 %)/11 (92 %)	<0.0001[c]
operative indication, n (%)			
inflammatory arthritis	1(4 %)	1 (8 %)	
instability	1 (4 %)	0	
cuff tear artrhopathy	8 (31 %)	0	
osteoarthritis	15 (58 %)	0	
revision arthroplasty	0	11 (92 %)	<0.0001[c]
		9	HSA to RSA
		1	TSA to RSA
		1	RSA to RSA

[a] Wilcoxon rank-sum test.
[b] Student's t-test.
[c] Fisher's exact test.

4. Discussion

The main finding of our study was that the structural bone grafts healed with no sign of radiological loosening around the glenoid component and satisfactory clinical results. There was no statistically significant difference in follow-up radiological component survival between the ATg and ALg groups.

There were more index revisions in the ALg group and it is plausible that also in one non-revision case it was not possible to correct the glenoid defect with the ATg technique. Preoperatively the amount of bone loss was statistically significantly greater in the ALg group compared to ATg group. However, the mean postoperative radiographic geometries of the RSA constructs were similar in both groups. Therefore, the bone graft constructs were bulkier in the ALg group than in the ATg group. In accordance with differences in preoperative states, the follow-up clinical scores were worse in the ALg group.

Our findings support the importance of osteoconductive and mechanical theory of bone grafting, with little additional benefit of the potential osteoinductive nature of the ATg grafts. It is of course more economical and also time sparing to use the humeral head ATg if possible. However, according to our results, when the humeral head is not sufficient, there is no need to harvest ATg iliac crest graft, if ALg fresh frozen bone is available. Furthermore, both spongious and cortical graft techniques may be utilized with essentially similar clinical results. It is noteworthy that also loading circumstances play an important role in bone graft healing.[12] In RSA the metaglene central pegs should be

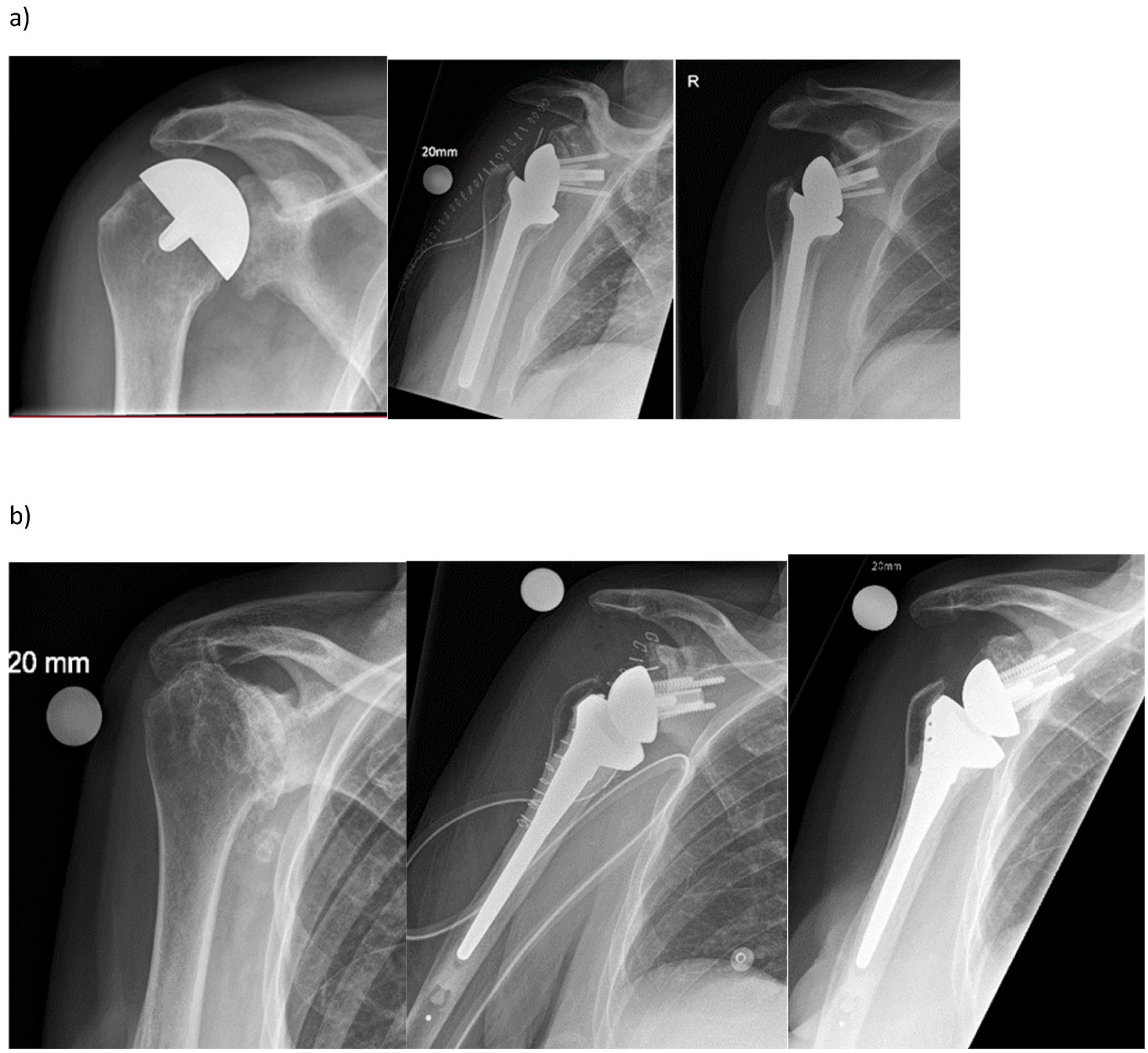

Fig. 2. Radiological images.

aimed parallel to the line of supraspinatus fossa in order to control for craniocaudal shearing forces.[18] In concordance with Wolff's law[19] in our series all grafts resorbed from the non-load bearing periphery of the graft, while most bone under the load-bearing metaglene and around the central peg was preserved. Despite 50 % of the grafts were only radiographically partially incorporated to the native glenoid, none of the metaglene components showed signs of radiographic loosening.

In previous reports the failure rate of structural glenoid bone grafts has been quite high. Ho et al. reported a graft resorption and component failure rate up to 25 % at a median of 14 months.[7] In their study the radiographic failure was associated with the retroversion on the glenoid contrary to our findings, and it may be that there were differences in the technical aspects of the procedure. In a recent meta-analysis, both primary RSA with glenoid bone graft and metal augmented glenoid techniques had good clinical outcomes.[20] In our series no metal augments were used and all the metaglenes were securely fixed to the native glenoid vault with a long central peg.

There are reports of the potential benefit of always lateralizing the glenoid, in order to gain a better ROM.[11] Nevertheless, active ROM is dependent on soft tissues and musculature, and therefore the theoretically optimal bony geometry may not result in better clinical results.[21] Glenosphere lateralization may also decrease notching, however with no influence on the functional outcome.[22] In our series the rate of notching was similar to previously reported.[23] It is also noteworthy that excessive lateralization and distalization of the glenosphere may lead to acromion stress fracture and complication.

The main strength of this study is a consecutive patient cohort treated at a tertiary hospital by experienced shoulder surgeons with good access to allograft bone through an institution based tissue bank (District of Turku University Hospital Musculoskeletal Tissue Bank).[24] Although we used several different implants, all the central pegs were similarly fixed in the native bone. Furthermore, we used patient reported outcome to evaluate the clinical results, and the radiographic images were analyzed by both a musculoskeletal radiologist and an orthopaedic surgeon. There are also noteworthy limitations. Firstly, this is a retrospective analysis of a heterogenous and small series of patients, with various degree of glenoid bone loss and with a short follow-up time, and a rather high drop-out rate. Secondly, we lack preoperative patient reported clinical outcome score data. Thirdly, although radiographs are reliable in the assessment of radiolucent lines and component loosening,[25] we lack follow-up CT data for the careful evaluation of the glenoid bone stock.

5. Conclusion

Glenoid bone grafting in conjunction with RSA is a safe and reliable method to restore the glenoid bone stock in short term follow-up. Although the indications may differ, there may be no significant

Table 2
Preoperative imaging data.

	ATg (N = 26)	ALg (N = 12)	p
Hamada, n (%)			
1	3 (12 %)	2 (20 %)	
2	1 (4 %)	1 (10 %)	
3	0	0	
4	20 (77 %)	5 (50 %)	
5	2 (8 %)	2 (20 %)	0.2848[b]
Walch, n (%)			
A1	0	1 (13 %)	
A2	14 (58 %)	2 (25 %)	
B1	0	0	
B2	5 (21 %)	0	
B3	1 (4 %)	1 (13 %)	
C	4 (17 %)	4 (50 %)	
D	0	0	0.0378[b]
Favard, n (%)			
E0	3 (12 %)	0	
E1	20 (77 %)	1 (20 %)	
E2	2 (8 %)	3 (60 %)	
E3	1 (4 %)	1 (20 %)	
E4	0	0	0.0101[b]
Retroversion, mean (SD)	16.3 (14.4)	23.5 (16.3)	0.2407[a]
CSA, mean (SD)	30.4 (4.9)	33.9 (11.9)	0.3931[a]

[W]Wilcoxon rank-sum test.
[a] Student's t-test.
[b] Fisher's exact test.

Table 3
a) Radiological follow-up data. b) Clinical results.

a) Radiological follow-up data

	ATg (N = 26)	ALg (N = 12)	p
years of follow-up, mean (SD)	2.6 (1.7)	3.3 (1.7)	0.2914[a]
CSA, mean (SD)	28.1 (7.0)	24.0 (19.5)	0.5081[a]
Sirveaux, n (%)			
no notching	17 (65 %)	9 (82 %)	
slight notching	7 (27 %)	1 (9 %)	
notching up to the lower screw	0	0	
notching above the lower screw	2 (8 %)	1 (9 %)	
notching reaching the central peg	0	0	0.5126[b]
incorporation of bone graft, n (%)			
graft fully incorporated	13 (50 %)	3 (30 %)	
graft partially incorporated	12 (46 %)	6 (60 %)	
graft resorbed	1 (4 %)	1 (10 %)	0.3956[b]
Length of central peg in native glenoid (mm), mean (SD)	17.0 (3.2)	14.3 (3.5)	0.0334[a]

b) Clinical results

	ATg (N = 26)	ALg (N = 12)	p
pain VAS, mean (SD) [median]	0.38 (1.10) [0.00]	1.62 (2.55) [0.40]	0.0121[c]
Constant, mean (SD) [median]	68.3 (9.6) [67.5]	55.9 (23.9) [58.0]	0.0267[c]
WOOS, mean (SD) [median]	89.2 (12.8) [93.6]	71.7 (21.3) [73.7]	0.0054[c]

[a] Student's t-test.
[b] Fisher's exact test.
[c] Wilcoxon rank-sum test.

difference in component survival between auto- and allograft bone grafting techniques. Longer-term follow-up is needed to assess the final outcome with regard to these techniques.

CRediT authorship contribution statement

Kaisa Lehtimäki: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Writing – original draft, Project administration. **Milja Holstila:** Investigation. **Keijo Mäkelä:** Supervision, Writing – review & editing. **Juha Kukkonen:** Supervision, Writing – review & editing. **Kari Tirkkonen:** Data curation, Investigation. **Jenni Harjula:** Data curation, Investigation. **Tommi Kauko:** Methodology, Software, Formal analysis, Validation, Visualization. **Ville Äärimaa:** Conceptualization, Formal analysis, Supervision, Writing – original draft.

Ethical statement

The Work has been carried out in accordance with Declaration of Helsinki.

Disclosure of authors financial interests or relationships

The authors, their immediate families, and any research foundation with which they are affiliated did not receive any financial payments or other benefits from any commercial entity related to the subject of this article. This study was funded by the University Hospital of Turku.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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