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Arthroscopic primary repair of proximal anterior cruciate ligament tears: outcomes of the first 56 consecutive patients and the role of additional internal bracing

Anne Jonkergouw[1] · **Jelle P. van der List**[1] · **Gregory S. DiFelice**[1]

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Abstract

Purpose Recent outcomes of arthroscopic primary repair of proximal anterior cruciate ligament (ACL) tears have been promising in small cohort studies. The purpose of this study was to assess outcomes of arthroscopic ACL repair in a larger cohort and to assess the role of additional augmentation.

Methods The first 56 consecutive patients that underwent arthroscopic ACL repair were examined at minimum 2-year follow-up. The latter 27 patients [48.2% (27/56)] received additional internal bracing with ACL repair. All 56 patients were included (100% follow-up). Mean age at surgery was 33.5 ± 11.3 years (59% male) and mean follow-up 3.2 ± 1.7 years. Clinical examination was performed using the objective International Knee Documentation Committee (IKDC) form. Subjective outcomes were obtained using the Lysholm, modified Cincinnati, Single Assessment Numeric Evaluation (SANE), and subjective IKDC scores.

Results Six repairs (10.7%) failed and four additional patients underwent reoperation (7.1%): two for meniscus tears and two for suture anchor irritation. Objective IKDC scores were A in 38 (73%), B in 8 (15%) and C/D in 6 (12%) patients. Mean Lysholm score was 94 ± 7.6, modified Cincinnati 94 ± 8.9, SANE 90 ± 12.5, pre-injury Tegner 6.7 ± 1.5, current Tegner 6.2 ± 1.5, and subjective IKDC 90 ± 10.9. Failures rates were 7.4% with and 13.8% without internal bracing ($P = 0.672$). There were no statistically significant or clinically relevant differences in subjective outcomes.

Conclusion Arthroscopic primary repair has resulted in good objective and subjective outcomes at 3.2-year follow-up in a carefully selected population. The role of additional internal bracing is possibly beneficial, but larger groups are needed to assess this.

Level of evidence III.

Keywords Knee · Anterior cruciate ligament · Primary repair · Primary ACL repair · Proximal ACL tear

Abbreviations

ACL	Anterior cruciate ligament
AM	Anteromedial
IKDC	International Knee Documentation Committee
SANE	Single Assessment Numeric Evaluation
SDs	Standard deviations

Introduction

Primary repair of anterior cruciate ligament (ACL) tears was the standard of care for all ACL tears until the early 1990s, but fell out of favor due to disappointing mid-term follow-up outcomes [18, 40, 44, 46, 47]. Recently, there has been a renewed interest in primary repair due to several factors. First of all, recent research has shown that primary repair should only be performed in proximal tears due to better vascularity [42] and good healing potential [32] and outcomes of primary repair are indeed better in proximal tears compared to midsubstance tears in both historical [46] and modern-day studies [12, 24]. Second, minimal invasive arthroscopy techniques are available nowadays with early rehabilitation that were both not available or commonly used during the open repair era [40, 44, 47]. Finally, researchers

✉ Jelle P. van der List
jpjvanderlistmd@gmail.com

Anne Jonkergouw
jonkergouwa@hss.edu

[1] Orthopaedic Sports Medicine and Trauma Service, Department of Orthopaedic Surgery, Hospital for Special Surgery, NewYork-Presbyterian, Weill Medical College of Cornell University, 525 East 68th Street, Starr 2, New York, NY 10021, USA

and surgeons have been pursuing the concept of primary repair because of the (potential) advantages: the ligament is preserved with its proprioception, graft side morbidity can be prevented [5, 23], revision surgery is similar to primary reconstruction which is not the case with reconstruction surgery [20, 25, 26], and it may potentially decrease the incidence of osteoarthritis [30, 39].

Subsequently, several studies have reported excellent outcomes using primary ACL repair in predominantly small case series over the last 5 years with various techniques. In these studies, excellent outcomes of arthroscopically reattaching proximally avulsed ACLs back to the femoral footprint have been reported using suture anchors [1, 6, 10, 11, 19] or transosseous tunnels [17, 29, 38]. Furthermore, some groups have also advocated augmenting the primary repair construct by either internal suture augmentation [17, 38] or dynamic intraligamentary stabilization [3, 4, 13, 24, 28]. The rationale of this augmentation is to provide additional stability to the repaired ligament and protect its healing during early mobilization [17, 38, 43, 47]. The clinical benefits of internal bracing have not yet been assessed, although preclinical studies have shown improved healing and biomechanical properties of the ACL by adding a mechanical augmentation to a repaired ACL [31, 35, 36].

The purpose of this study was (I) to evaluate the outcomes of arthroscopic ACL repair in a larger cohort and (II) to assess the role of additional suture augmentation on the outcomes. It was hypothesized that arthroscopic ACL repair would lead to good knee stability and subjective outcomes at final follow-up, regardless of additional internal bracing.

Methods

Patient selection

In this retrospective study, approval from the Institutional Review Board was obtained to search the database of the senior author for all surgically treated patients with isolated complete ACL tears between December 2008 and June 2016. A total of 190 patients were operated of which 134 were treated with ACL reconstruction due to midsubstance tears or insufficient tissue quality. A total of 56 (29%) patients were treated with arthroscopic primary ACL repair and all of these patients could be included (100%) with minimum 2-year follow-up. This study, therefore, consisted of the first 56 consecutive patients with complete isolated proximal ACL tears that were treated with arthroscopic primary ACL repair.

Patient demographics

Fifty-two patients (92%) were seen in clinic and four (7%) provided information and patient-reported outcomes by email at a mean follow-up of 3.2 ± 1.7 years (range 2–9). Mean age at surgery was 33.5 ± 11.3 years (range 14–57) and BMI was 25 kg/m^2 (range 19–35) (Table 1). Twenty-three patients (41.1%) had meniscal injury and 16 (28.6%) chondral injury. The most common mechanisms of injury were skiing (25.5%), basketball (16.4%), and soccer injuries (9.1%). Mean time to surgery was 203 days after injury (range 5 days–11 years). Twenty-four patients (42.9%) with excellent tissue quality were treated greater than 6 weeks from injury.

Study protocol

Each patient was contacted and invited for evaluation of outcomes. First, it was assessed if failure (symptomatic instability or rerupture) or reoperation had occurred and the surgeon scored the International Knee Documentation Committee (IKDC) Objective Score. Then, patient-reported outcome scores were collected, consisting of the Lysholm Knee Score [27, 48], modified Cincinnati Score [33, 37], Single Assessment Numeric Evaluation (SANE) [37, 48], pre-injury and current Tegner Activity Scales [41], and IKDC Subjective

Table 1 Patient demographics of ACL repair and ACL repair with additional internal bracing

	Entire cohort ($N=56$)	ACL repair ($N=29$)	ACL repair + IB ($N=27$)	P value
Age (years), mean ± SD	33.5 ± 11.3	37.0 ± 11.3	29.6 ± 10.1	0.013
Male, N (%)	33 (58.9%)	18 (62.1%)	15 (55.6%)	0.621
BMI (kg/m^2), mean ± SD	25.2 ± 3.8	25.8 ± 4.1	24.6 ± 3.3	0.323
Concomitant injury, N (%)				
MM injury	11 (19.6%)	5 (17.9%)	6 (22.2%)	0.865
LM injury	14 (25.0%)	6 (21.4%)	8 (29.6%)	0.440
Chondral injury	16 (28.6%)	10 (35.7%)	6 (22.2%)	0.201
Time to surgery (days), median (range)	35 (5–4018)	38 (9–4018)	26 (5–155)	0.201

MM medial meniscus, *LM* lateral meniscus

Score [14]. In case no visit could be planned, patients were asked if they underwent subsequent surgeries or experienced recurrent instability and to provide patient-reported outcomes by email. In addition, the medical records of all patients were reviewed to record demographics, injury patterns, details of the operative procedure and postoperative rehabilitation.

Surgical technique

All surgeries were performed by the senior author (GSD). Arthroscopic primary repair was selectively performed in patients with a proximal ACL tear that had sufficient distal remnant length and tissue quality to reapproximate the remnant to the femoral footprint. The technique of ACL repair with internal bracing has been previously described in detail [9, 43]. In brief, the anteromedial (AM) and posterolateral bundle were each sutured in a Bunnell-type pattern from distal to proximal, using No. 2 FiberWire and TigerWire sutures (Arthrex, Naples, FL, USA), respectively (Fig. 1). Each bundle was then reapproximated to its footprint using a BioComposite SwiveLock suture anchor (Arthrex). Prior to fixation, the footprint and notch were roughened with a shaver to induce a local healing response.

In the latter 27 of 56 patients, a 2-mm wide InternalBrace (Arthrex) was added to the ACL repair. The AM suture anchor was preloaded with this InternalBrace, which was channeled through a tunnel in the tibia that was drilled using an ACL DrillGuide (Arthex). The InternalBrace exited the anteromedial tibial cortex and was fixed using a BioComposite SwiveLock suture anchor after cycling the knee and tensioning in near full extension.

Postoperative rehabilitation

Post-operatively, all patients wore a hinged brace. At first, weight bearing was allowed with the brace locked in extension, until quadriceps muscle control had been regained (examined at approximately 4 weeks post-operatively). In cases, where meniscal repair had been performed, patients

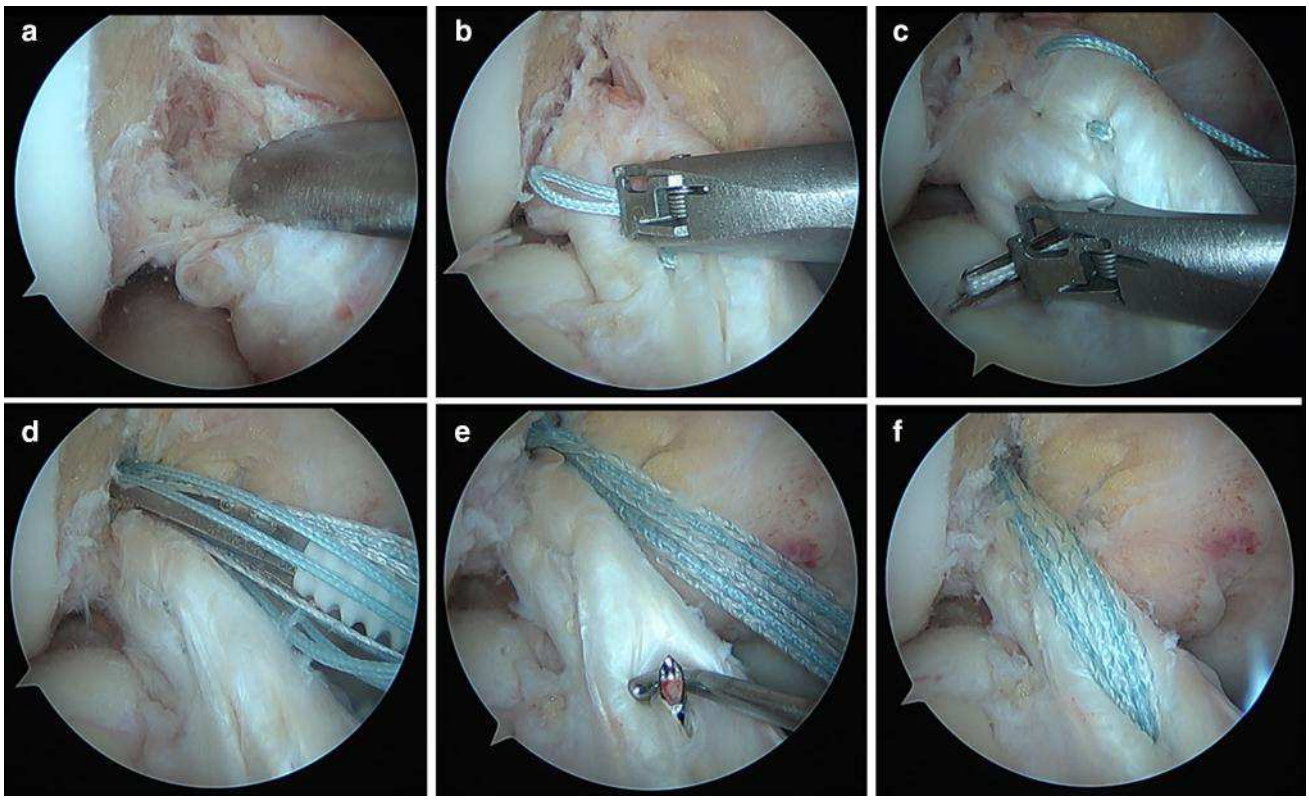

Fig. 1 Arthroscopic view of a right knee, viewed from the anterolateral portal, with the patient supine and the knee at 90° of flexion. **a** Proximal avulsion tear of the anterior cruciate ligament (ACL) is being confirmed using a probe to displace the ligament from the femoral footprint. **b** Anteromedial (AM) ACL bundle is sutured with locking stitches of No 2. FiberWire using a Scorpion suture passer. **c** Posterolateral (PL) ACL bundle is subsequently sutured with a No. 2 TigerWire. **d** 4.75-mm Vented BioComposite SwiveLock suture anchor that is preloaded with FiberTape is deployed into the femur at the footprint of the AM bundle. The PL bundle has been reattached with an unloaded suture anchor. **e** Straight Microsuture Lasso is being inserted through a 2.4-mm tunnel through the tibia from the anteromedial cortex into the anterior half of the tibial ACL insertion. **f** FiberTape is shuttled along the repaired ACL and down through the tibia, where it is fixed at the cortex using a suture anchor

were restricted to partial weight bearing and flexion to a maximum of 90° for 6 weeks. In general, formal physical therapy was started after 4 weeks. Patients were seen at 1 week, 1 month, 3 months, and 6 months post-operatively, during which it was reviewed if patients were ready for return to sports using examination of quadriceps muscle strength, rehabilitation milestones, and confidence to return to sports.

Statistical analysis

Statistical analyses were performed using the SPSS 24.0 software (IBM Corporation, Armonk, NY, USA). Continuous variables were described with means ± standard deviations (SDs) and their ranges or medians with ranges (if not normally distributed), and nominal variables were described with frequencies (%). Outcomes of subgroups were compared, using independent *t* tests for continuous variables and Chi-squared tests or Fisher exact tests (for samples with a value < 5 in the contingency table) for nominal data. All tests were two-sided and a difference of $P < 0.05$ was considered statistically significant.

Results

Baseline characteristics

Treatment consisted of arthroscopic ACL repair for the first 29 patients (51.8%) and arthroscopic ACL repair with additional internal bracing for the latter 27 patients (48.2%). There were no significant differences in injury pattern (meniscal and chondral injuries) and time to surgery between ACL repairs with and without internal bracing (Table 1). Patients undergoing ACL repair without additional internal bracing were older than patients with additional internal bracing (37.0 ± 2.1 vs. 29.6 ± 10.0 years; $P = 0.013$) due to more restricted patient selection at the start of this procedure and had longer follow-up (4.0 ± 2.0 years vs. 2.4 ± 0.7 years; $P = 0.001$).

Objective outcomes

At final follow-up, six ACL repairs (10.7%) had failed at a mean time of 1.0 years (range 6–17 months) after surgery (Table 2). Each failure was caused by re-injury. Subsequently, four failed ACL repairs were treated with an uncomplicated ACL reconstruction and two were treated conservatively. Furthermore, four additional patients (7.1%) underwent a subsequent surgery: two for a medial meniscus tear and two for tibial suture anchor removal (Table 2). There was no statistical significant difference in failure rate ($P = 0.672$) between ACL repair with (2/27; 7.4%) and without (4/29; 13.8%) additional internal bracing or in reoperation rate ($P > 0.999$) between these groups [2/27 (7.4%) vs. 2/29 (6.9%), respectively]. In addition, no effect of age or time to surgery on clinical success was found. Objective IKDC scores of the 52 examined patients were A in 38 (73%), B in 8 (15%), and C/D in 6 (12%) patients and these did not differ between both groups.

Patient-reported outcomes

The mean patient-reported outcomes of the entire cohort were a Lysholm of 94 ± 7.6 (range 68–100), modified Cincinnati of 94 ± 8.9 (range 59–100), SANE of 90 ± 12.5 (range 40–100), and subjective IKDC of 90 ± 10.9 (range 60–100) (Table 3). Tegner activity level changed from 6.7 ± 1.5 (range 3–10) pre-injury to 6.2 ± 1.5 (range 3–9) at follow-up. The subjective scores did not significantly

Table 2 Subsequent treatments after ACL repair of 56 patients at 3.2-year follow-up

	Initial treatment	Mechanism	Timing (years)	Subsequent treatment
ACL re-tear				
#1	ACL repair	Stair-climbing injury	0.6	Conservative
#2	ACL repair	Fall	0.9	Conservative
#3	ACL repair	Soccer injury	0.8	ACL reconstruction
#4	ACL repair	Rugby injury	1.1	ACL reconstruction
#5	ACL repair + IB	Soccer injury	1.4	ACL reconstruction
#6	ACL repair + IB	Gymnastics injury	1.1	ACL reconstruction
Meniscus injury				
#1	ACL repair	Football injury	2.8	MM debridement
#2	ACL repair	Soccer injury	3.3	MM repair
Hardware irritation				
#1	ACL repair + IB	Tibial anchor placement	1.4	Partial anchor removal
#2	ACL repair + IB	Tibial anchor placement	1.6	Partial anchor removal

IB internal brace, *MM* medial meniscus

Table 3 Patient-reported outcomes after successful ACL repair in 50 patients at 3.2-year follow-up

	Entire cohort ($N=50$)	ACL repair ($N=25$)	ACL repair + IB ($N=25$)	P value
Lysholm, mean ± SD	94.2 ± 7.6	95.2 ± 7.4	93.0 ± 7.9	0.324
Modified Cincinnati, mean ± SD	93.5 ± 8.9	94.1 ± 8.3	92.9 ± 9.5	0.654
SANE, mean ± SD	89.7 ± 12.5	89.3 ± 14.5	90.0 ± 10.2	0.844
Tegner pre-injury, mean ± SD	6.7 ± 1.5	6.4 ± 1.4	7.0 ± 1.6	0.166
Tegner currently, mean ± SD	6.2 ± 1.5	6.0 ± 1.3	6.4 ± 1.7	0.483
Subjective IKDC, mean ± SD	90.0 ± 10.9	90.6 ± 12.1	89.4 ± 9.6	0.699

SANE Single Assessment Numeric Evaluation, *IKDC* International Knee Documentation Committee

differ between ACL repair with and without internal bracing (Table 3).

Discussion

The most important findings of the present study were that the good short-term clinical outcomes of ACL repair were achieved using arthroscopic ACL repair on selected patients with proximal ACL tears and that no differences in complication rate, reoperation rate, or patient-reported outcomes were found between ACL repair with and without additional internal augmentation. In this study, 48 of the 54 examined patients (88.9%) had stable knees, and 50 of 56 patients (89.3%) reported excellent subjective outcomes at a mean of 3.2-year follow-up. At final follow-up, six ACL repairs (10.7%) had failed and four additional patients (7.1%) required a subsequent surgery for painful hardware or meniscal injury.

This study reported on a large cohort of patients that have undergone modern arthroscopic ACL repair followed by early rehabilitation in the literature. Previous recent studies, consisting of smaller cohorts and with variable ACL repair techniques, showed results similar to the current study [1, 6, 17, 19, 29]. Achtnich et al. [1] reported a 15% failure rate out of 20 ACL repairs at 28-month (2.3-year) follow-up, using one suture anchor for ACL fixation at the femoral footprint. They noted that failures were associated with noncompliance with the rehabilitation protocol [1]. Hoffmann et al. [19] also used an ACL repair technique with one suture anchor and reported that 25% of 12 patients had failed or suffered from residual laxity at mean follow-up of 79 months (6.6 years). As no re-injuries were noted, they assumed that the ACLs did not heal properly in these cases [19]. Furthermore, Bigoni et al. [6] and Smith et al. [38] reported no failures of ACL repairs in five and three pediatric patients, respectively. More historical studies have described ACL repairs using open techniques and subsequent knee immobilization and are, therefore, less comparable to the current outcomes.

Comparing ACL repair with and without additional internal bracing, this study failed to show a clinical benefit of additional internal bracing to primary ACL repair. However, it should be noted that this comparison was underpowered, and it is possible that failure rates will be different in a larger cohort of patients, although the follow-up in the internal bracing group was shorter. Preclinical studies have shown superior biomechanical results when adding an internal brace (often described as suture augmentation) [15, 36, 47].

Recently, Van Heusden et al. [17] reported excellent outcomes of primary repair with additional internal bracing in 42 patients with 4.8% failures at 2-year follow-up. Heitmann et al. [15] tested different types of suture augmentation and showed higher load-to-failure of augmented ACL repairs (464–624 N) compared with ACL repairs without augmentation (177 N) and with ACL reconstructions with hamstring tendons (362 N). Seitz et al. [36] showed significantly higher stiffness, tensile strength, and less anteroposterior laxity of augmented ACLs. Similarly, Murray et al. [31] reported that additional stabilization between the tibia and femur improves structural properties of ACL repairs. However, no clinical data are available to suggest functional benefits of additional internal bracing.

Importantly, two patients reported hardware irritation at the tibial cortex from the suture anchor used for internal brace fixation, who required additional surgery for removal of this hardware. To prevent such irritation, the tibial suture anchor was deployed at least as deep as the cortex and no further cases of hardware irritation occurred. Overall, implementation of an internal brace seems safe and no failures were related to the hardware, although no clinical benefits were suggested. As a result, the senior author now selectively performs additional internal bracing in patients at high-risk for failure, including those of young age, with generalized hyperlaxity, of younger female patients or those competing in high-level pivoting sports. It could be argued that internal bracing should be included on all repairs in light of the minimal complications that have been encountered, while not factoring in costs. Larger studies with more power will be needed to answer this question.

When comparing outcomes of ACL repair with ACL reconstruction in the literature, the failure rates of ACL repair in this study are similar to slightly higher than ACL reconstruction outcomes. However, ACL reconstruction can be associated with significant postoperative quadriceps muscle weakness and knee stiffness, which require a strenuous and time-consuming rehabilitation program [34]. A previous study by our group [45] found that patients have greater postoperative range of motion after ACL repair than ACL reconstruction at 1 week (89° vs. 61°) and at 1 month (125° vs. 116°), in addition to fewer complications and a shorter operation time. Although good knee stability is generally achieved with ACL reconstruction, recent studies have noted that return-to-sport activity rates after ACL reconstruction are not as high as expected, and that development of long-term osteoarthritis is a significant risk [2, 8, 21]. There are preclinical data that suggests that ACL repair results in a lower risk of osteoarthritis than both reconstruction and conservative treatment [30]. Considering the less invasive nature of ACL repair, future studies are needed to assess if ACL repair might also lead to a lower incidence of long-term osteoarthritis in humans.

Limitations exist in this study. Despite the relative large cohort of patients evaluated, this study is a retrospective study and is subject to selection bias, although this risk is decreased within the cohort, because consecutive patients were included without any lost to follow-up. Furthermore, the comparison of outcomes of ACL repair with and without additional internal bracing is underpowered and it is, therefore, possible that the failure rate of primary repair with additional augmentation may be lower than primary repair without augmentation. However, this study shows that, in general, arthroscopic ACL repair is safe regardless of internal bracing, with an acceptable failure rate and excellent functional outcomes. In addition, the age of patients varied between the treatment groups with and without internal bracing, with younger patients in the group with additional internal bracing. Since younger age is potentially associated with inferior results, as seen after ACL reconstruction, this factor could have suppressed actual differences in outcomes between the treatment groups; although on the contrary, the group with additional internal bracing was treated when the surgeon had more experience with ACL repair. Finally, no objective KT-1000 laxity measurements were performed in this study. Several studies have previously showed that good stability can be achieved with primary ACL repair as measured on KT-1000 laxity [1, 3, 6, 7, 11, 16, 19, 22, 29]. These limitations support neither the use or abandonment of internal bracing. Studies matched by age and gender will be needed to better assess failure rates and outcomes between both groups, as well as studies reporting outcomes in a prospective design and comparing the outcomes with reconstruction and conservative treatment.

Conclusion

Arthroscopic primary repair has resulted in good objective and patient-reported outcomes at 3.2-year follow-up in a carefully selected patient population of proximal tears and sufficient tissue quality. The role of additional internal bracing is possibly beneficial, but larger groups of patients are needed to assess this.

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Compliance with ethical standards

Conflict of interest Gregory S. DiFelice is a paid consultant for Arthrex and receives research funding from Arthrex, and Jelle P. van der List is a paid consultant for Arthrex. Anne Jonkergouw declares no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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