Zhong et al. BMC Musculoskeletal Disorders (2025) 26:205
https://doi.org/10.1186/s12891-025-08462-w

BMC Musculoskeletal Disorders

RESEARCH Open Access

Comparison of medium- and long-term total knee arthroplasty follow-up with or without tourniquet

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Abstract

Background Applying non-tourniquet technology in total knee arthroplasty (TKA) is becoming increasingly popular. However, there is no consensus on its effect on the service life of knee prostheses. This study examined the effect of tourniquet use on cement penetration and radiolucent line (RLL) to assess whether the use of tournique in TKA affects prosthesis survival.

Methods We retrospectively analyzed 166 patients admitted to our hospital between January 1, 2014, and June 1, 2015, who met the inclusion criteria. The patients were divided into the tourniquet (80 cases) and non-tourniquet groups (86 cases) according to whether a tourniquet was used during the operation. We compared the preoperative data and related complications between both groups. Hip-knee-ankle (HKA), medial proximal tibial angle (MPTA) and the penetration depth of bone cement on the osteotomy surface was measured according to postoperative imaging data. Furthermore, the probability of occurrence of radio-clear lines around the prosthesis was observed.

Results A total of 166 patients were enrolled with a mean age of 68.52 ± 4.74 years and a mean follow-up time of 105.67 ± 5.98 years. No significant demographic differences were observed between the two groups ($P > 0.05$). Revision surgery was performed for one patient in each group due to aseptic loosening of the prosthesis. The preoperative and postoperative knee association function scores (HSS), knee range of motion, HKA, and MPTA between the two groups did not differ significantly ($P > 0.05$). In the lateral observation of zone femur 3A and the average observation area of the femur, the penetration depth of the osteotomy surface were significantly different between the two groups ($P < 0.05$). The incidence of radiolucent lines differed slightly between both groups in different observation areas,but the revision rate did not differ significantly between the two groups ($P > 0.05$).

Conclusion In the long term, TKA without tournique use can achieve clinical effects comparable to the use of tourniquet in many aspects, such as prosthesis stability, prosthesis survival rate, reoperations rate, knee range of motion, and knee functionality.

Keywords Joint arthroplasty, Tourniquet, Prosthesis, Bone cement, Radiolucent line

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Introduction

Recently, revision surgery has shown an increasing trend due to the increased demand for total knee arthroplasty (TKA) and expansion of surgical indications. According to the American Academy of Orthopaedic Surgeons, the number of TKA revision cases by 2030 will increase to six times that of 2005 [1]. Aseptic loosening is a major indication for knee revision surgery, accounting for 28.7% of cases usually occurring at the bone-cement interface [2]. Osteotomy surface and implant stability are affected by many factors. The depth of bone cement penetration into the cancellous bone is crucial for a successful initial TKA. It is related to bone cement thickness, placement time, penetration conditions, and many other factors [3–5]. In theory, the bone cement penetration depth determines the implant's tensile strength in the vertical direction and the shear strength in the horizontal direction. Bone cement covering 3–4 mm between the tibial implant and the tibial trabecula is best to avoid surrounding osteolysis and prosthesis loosening [6]. Cancellous bones contain an interstitial space, and when the prosthesis is installed, properly pressing the unsolidified bone cement can better penetrate the bone trabeculae interstitial space. In contrast, blood seepage and fat drops on the osteotomy surface blocks bone cement infiltration and reduce its viscosity. Relevant studies have shown that bleeding and lipid droplets on the osteotomy surface reduce bone cement viscosity by approximately 50%, decreasing the thickness of the bone cement penetrating the cancellous bone [7], which may affect the service life of prostheses.

In order to ensure the bone cement can penetrate smoothly. Tourniquet is used in traditional TKA because it can effectively reduce bleeding from the osteotomy surface, provide a dry osteotomy surface, facilitate bone cement occlusion, and improve prosthesis placement quality. Besides, It can ensures a clear surgical field, reduces frequent hemostatic operations, makes the operation smoother, shortens the operation time, and reduces infection risk [8, 9]. The short-term outcome of knee arthroplasty was evaluated based on the prosthesis stability and the knee joint range of motion (ROM). Long-term outcomes were primarily evaluated through survival analysis with revision surgery as the endpoint [10].With the popularity of the enhanced recovery after surgery (ERAS) concept in perioperative TKA [11], many researchers still do not advocate using tourniquets during surgery. Using intraoperative tourniquets increases invisible postoperative blood loss and ischemia–reperfusion injury risk, aggravates swelling of the affected limb, and is not conducive to early postoperative functional exercise. Notably, many researchers have studied whether using tourniquets affects the stability and survival period of knee prostheses. However, no consensus has been reached [9]. Certain scholars believe that using tourniquets reduces the service life of knee prostheses. In contrast, others have an opposite conclusion, believing that using tourniquets does not affect the survival period of prostheses. Currently, there are no long-term follow-up studies to determine whether intraoperative tourniquet use affects the useful life of prostheses.

This study's objectives were: i) to compare the differences in knee function and quality of life between the two groups during follow-up. ii) to compare whether the use of a tourniquet affected bone cement penetration and the probability of generating radioactive rays by imaging measurements, and iii) to compare whether the use of a tourniquet affects the survival of knee prostheses during long-term follow-up.

Materials and methods

Inclusion and exclusion criteria

The medical ethics committee approved this study, and all participants provided informed consent. The inclusion criteria were: (1) patients with degenerative osteoarthritis of the knee who underwent knee arthroplasty for the first time, (2) Age 60–75 years old, body mass index < 35 kg/m^2, and (3) all operations had been performed by the same senior physician with the same surgical approach. The exclusion criteria were: (1) patients with bilateral primary knee arthroplasty, (2) serious knee deformity, internal and external inversion > 20°, and (3) patients requiring secondary revision due to periprosthetic fractures.

Study design and participants

We retrospectively analyzed 254 patients with knee arthritis treated in our hospital from January 1, 2014, to June 1, 2015, among them, 217 patients met the inclusion criteria, 20 met the exclusion criteria, and a total of 197 patients were screened. Among the above 197 patients who met the inclusion and exclusion criteria, 8 patients who died due to extra-articular diseases, and 23 patients without follow-up information. Finally, 166 patients were included in this study. Our hospital's surgical concept changed in 2014, and the patients were divided into two groups according to whether tourniquets were used during the operation. There were 80 cases in the tourniquet (T) group, including 31 males and 49 females, with an average age of 68.07 ± 6.75 years, and 86 cases in the non-tourniquet (NT) group, including 35 males and 51 females, with an average age of 68.41 ± 6.52 years. Before surgery, we evaluated the severity of knee arthritis by radiology using the Kellgren and Lawrence scores. Table 1 shows the general information of the patients in the two groups.

Surgical technique

The patient was placed in the supine position and the surgical field was routinely disinfected and covered with a cloth. In group T, a tourniquet (pressure 260 mmHg)

Table 1 Basic demographic data of the two groups

Characteristics	Group T	Group NT	Statistics	*P*-value
Age	68.027 ± 4.419	68.95 ± 5.004	1.256	0.211
Gender(men/women)	31/49	35/51	0.066	0.798
Side (Left/Right)	38/42	44/42	0.222	0.637
BMI	29.768 ± 3.791	30.275 ± 3.442	0.903	0.368
Kellgren and Lawrence (3/4)	36/44	49/37	0.066	0.798

Group T tourniquet groups, *Group NT* non-tourniquet groups, *BMI* body mass index

was applied throughout the entire process, whereas no tourniquet was applied in Group NT. All patients were administered 1 g tranexamic acid intravenously before surgery. A longitudinal incision was made in the anterior median, starting at the proximal side of the patella (5–10 cm) and ending at the tibial tubercle. A deep incision was made along the medial side of the patella to expose the joint cavity. According to certain operating procedures, the femoral end osteotomy was performed first, followed by the posterior tibial end osteotomy; the lower limb vertical line was restored, and bone cement was fully mixed when required. Then, the tibia and femur prostheses were implanted, excess bone cement was removed after it had solidified, and a polyethylene liner was installed and rinsed with a washing gun. The tourniquet in the T group was loosened for careful electrocoagulation. In contrast, the NT group had already performed inadvertent electrocoagulation at the bleeding site intraoperatively. Indwelling drainage tube was placed in both groups. And then, all patients were subsequently sutured layer-by-layer, bandaged with gauze, cotton pads, and elastic bandages.

The two groups had similar postoperative treatment methods, including swelling reduction, pain relief, anti-inflammatory therapy, thrombosis prevention, and other routine treatments. Patients were instructed to exercise the ankle pump and leg lift functions under guidance on the first-day post-surgery. On the second postoperative day, the wound dressing was changed, the wound drainage tube was removed, the dressing was bandaged, and the patient was instructed to perform knee joint and flexion function exercises, and walked with the help of a walker and then gradually transitioned to normal walking without walker.

Observation assessment

We compared all patient's perioperative data, including operation time, incision length, intraoperative blood loss, total blood loss, and length of hospital stay. Complications, such as wound infection, poor wound healing, and deep venous thrombosis (DVT) of the lower limbs, were recorded during follow-up. The hip knee ankle angle (HKA) and medial proximal tibial angle (MPTA) were measured before and after surgery. We measured

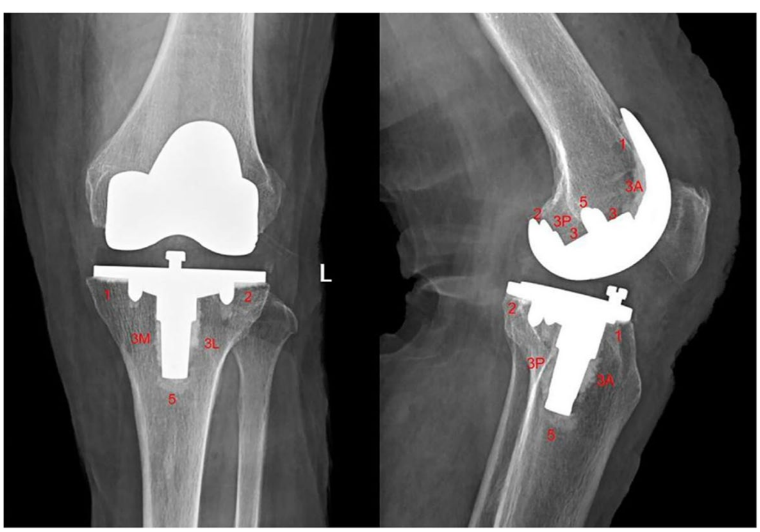

Fig. 1 Radiographic zones defined by the knee society radiographic evaluation system

the depth of bone cement penetration in each area of the postoperative radiographic prosthesis (Fig. 1). We identified the radiolucent line between the osteotomy surface and the prosthesis using radiography at the last follow-up. Preoperative and postoperative HSS and knee range of motion (ROM) were recorded in both groups during follow-up.

Data analyses

Data were measured independently and averaged from three uninformed individuals. Statistical analysis was performed using the statistical package for social sciences 26.0, and measurement data were presented as ($\overline{x} \pm s$). Normally distributed data was compared between both groups using an independent sample *t*-test, while counting data was compared using the χ^2 test or Fisher's exact test. The grade data between both groups were compared using the Mann–Whitney U test. Statistical significance was set at $P < 0.05$.

Results

General results and complications

Compared with the T group, the amount of intraoperative blood loss increased significantly($P < 0.05$), but the total blood loss did not differ significantly ($P > 0.05$). In addition, There was no significant difference of the length of hospital stays and the operative time between two groups.There were no blood transfusions in the T group and NTgroup, and both groups did not differ significantly ($P = 1.000$). No complications, such as DVT or pulmonary embolism, occurred in either group (Table 2).

Follow-up results

All patients were followed up completely. With regard to cumulative incidence of revision surgery, reoperations and complications, each group had one case of aseptic loosening requiring revision surgery(1.25% vs 1.16%), and no cases of infection revision was reported in either group. The remaining patients did not have implant displacement, loosening, or bone-cement fractures. A total of 3 patients in group T(3.75%) and 4 patients in group NT(4.65%) had poor incision healing. All of these patients experienced delayed incision healing after antibiotic therapy, daily dressing changes, and local physical therapy. Postoperative imaging data indicated that HKA and MPTA differed slightly between both groups, but the difference was not statistically significant between the two groups. The pain in both groups was significantly improved compared with that before surgery, and no patients with no improvement or even aggravation of symptoms. No significant differences were observed in the preoperative and postoperative HSS scores or knee ROM between the two groups (Table 3). At the last follow-up, we determined excellent and good outcomes based on the knee joint scores of both groups. In the T group, 75 cases were excellent, three were good, one was medium, and one was poor; the excellent and good rates were 97.5%. In the NT group, 81 cases were excellent, two were good, and three were medium; the excellent and good rates were 96.51%. See Table 3 for further details.

Cement penetration

The depth of cement penetration measured at different points in different areas for both patient groups differed slightly, but the overall difference was not large. We observed statistically significant differences between the zone femur 3A observed in the lateral view (1.717 ± 0.7901 vs 1.985 ± 0.759, $P = 0.027$) and the average observation zone of the femur (1.646 ± 0.395 vs 1.788 ± 0.372, $P = 0.018$). However, they did not indicate

Table 3 Follow-up data of the two groups

	Group T	Group NT	Statistics	*P*-value
Preop HKA	175.556 ± 2.030	175.033 ± 1.763	−1.776	0.078
Postop HKA	178.141 ± 1.163	177.738 ± 1.501	−1.923	0.056
Preop MPTA	85.621 ± 1.721	85.726 ± 1.827	0.379	0.705
Postop MPTA	88.527 ± 1.214	88.579 ± 1.414	0.256	0.798
Preop HSS	60.009 ± 6.595	60.721 ± 5.776	0.741	0.460
Postop HSS	89.815 ± 3.626	88.691 ± 4.197	−1.839	0.068
Preop ROM	109.700 ± 10.583	111.062 ± 9.155	0.888	0.376
Postop ROM	126.437 ± 8.559	125.822 ± 9.510	−0.437	0.663

HKA hip-knee-anke, *MPTA* medial proximal tibial angle, *HSS* knee association function scores, *ROM* range of motion

Table 2 Perioperative data of two groups of patients

	Group T	Group NT	Statistics	*P*-value
Operation time (min)	108.105 ± 18.197	112.367 ± 17.316	1.546	0.124
Hospital time (d)	9.735 ± 2.319	9.454 ± 2.110	−0.818	0.414
Follow-up time(mon)	106.508 ± 7.129	104.894 ± 4.569	−1.723	0.087
Intraoperative blood loss (ml)	159.714 ± 15.415	259.602 ± 28.176	28.596	0.000
Total blood loss (ml)	1054.275 ± 215.209	1073.401 ± 226.452	0.557	0.578

that tourniquet use affected the infiltration of bone cement into the osteotomy surface. We speculate that this may have something to do with measurement errors. No significant difference was observed in the mean penetration depth of the bone cement between both groups ($P > 0.05$) (Table 4).

Radiolucent lines

The radiolucent lines (RLL) occurred mostly in zones tibial 1 and 2 (anteroposterior view) 、zones tibial 1 and 2 (lateral views) and in zones femur 1 and 2. In the lateral view between both groups, zone tibial 2 (35% vs. 15.12%, $P = 0.003$) and zone femur 1 (31.25% vs. 15.12%, $P = 0.014$) differed significantly, whereas there were no statistically significant differences in other areas ($P > 0.05$). There was no statistically significant difference in the probability of progressive RLLs ($P > 0.05$) (Table 5).

Discussion

Our study found that the use of tourniquet technique in TKA was similar to that of intraoperative tourniquet use in terms of prosthesis survival, reoperation, complications, knee function, and health status. With the popularity of ERAS, the use of tourniquets has decreased. According to relevant studies, the proportion of tourniquets used for knee arthroplasty has decreased from 90% in 2011 to 70% in 2014 [12]. The tourniquet has certain benefits, but greater pressure causes compression injury to the thigh muscle, reduces the strength of the quadriceps muscle, aggravates postoperative pain, and delays postoperative rehabilitation [13, 14]. Regarding perioperative blood management of TKA, long-term tourniquet compression will lead to increased microvascular permeability, anoxia of vascular wall cells, slow blood flow, hypercoagulability aggravation, and increased probability of DVT [15–18]. In addition, it is not conducive to the maintenance of intraoperative blood pressure, and the location of vascular injury prone to ischemia–reperfusion injury, cannot be detected immediately [15, 16]. Notably, some scholars have proposed that tourniquets reduce the amount of intraoperative overt blood loss but increase the amount of postoperative recessive blood loss. Zan et al. concluded that recessive blood loss after TKA exceeds 50% of the total blood loss [17], and is not dominant if the role of tourniquets in blood management is weighed using the total blood loss [18]. Schnettler et al. showed that the total blood loss with tourniquet was 1215.34 ± 370.31 ml, while the total blood loss without tourniquet was 1007.22 ± 385.32 ml in their study, which

Table 5 The occurrence of RLL at the last follow-up(n)

View	Zone	Group T	Group NT	Statistics	*P*-value
AP	Tibial 1	25/55	26/60	0.020	0.887
	Tibial 2	30/50	22/64	2.737	0.098
	Tibial 3 M	1/79	2/84	0.270	0.603
	Tibial 3L	2/78	2/84	0.005	0.942
	Tibial 5	3/77	4/82	0.083	0.773
Lateral	Tibial 1	21/59	26/60	0.324	0.569
	Tibial 2	28/52	13/73	8.810	**0.003**
	Tibial 3A	1/79	2/84	0.270	0.603
	Tibial 3P	2/78	4/82	0.551	0.458
	Tibial 5	4/76	4/82	0.011	0.916
	Femur 1	25/55	13/73	6.112	**0.014**
	Femur 2	20/60	26/60	0.566	0.452
	Femur 3	2/78	1/85	-	0.609
	Femur 3A	0/80	1/85	-	1.000
	Femur 3P	2/78	2/84	-	1.000
	Femur 5	0/80	1/85	-	1.000
Progress RLLs		20/60	18/68	0.389	0.553

AP anterior–posterior, *RLL* radiolucent lines

Table 4 Cement penetration (in mm) by radiographic zone

View	Zone	Group T	Group NT	Statistics	*P*-value
AP	Tibial 1	2.049 ± 0.709	1.975 ± 0.720	−0.661	0.510
	Tibial 2	1.889 ± 0.683	1.983 ± 0.729	0.862	0.390
	Tibial average	1.976 ± 0.496	1.977 ± 0.445	0.007	0.995
Lateral	Tibial 1	2.212 ± 0.907	2.271 ± 0.829	0.432	0.666
	Tibial 2	2.442 ± 0.941	2.479 ± 0.826	0.270	0.787
	Tibial average	2.333 ± 0.649	2.380 ± 0.607	0.490	0.625
	Femur 3	1.604 ± 0.539	1.709 ± 0.563	1.227	0.222
	Femur 3A	1.717 ± 0.790	1.985 ± 0.759	2.231	**0.027**
	Femur 3P	1.617 ± 0.629	1.670 ± 0.699	0.512	0.609
	Femur averagr	1.646 ± 0.395	1.788 ± 0.372	2.387	**0.018**
Overall average across 7 zones		1.949 ± 0.271	2.017 ± 0.274	1.624	0.106

Group T tourniquet groups, *Group NT* non-tourniquet groups, *AP* anterior–posterior was similar to our study results [18]. In the NT group, the total blood loss was 1073.401 ± 226.452 ml. The total blood loss in the T group was 1054.275 ± 215.209 ml, and the difference was not statistically significant, indicating that the use of tourniquet in TKA did not affect the total blood loss.This was also confirmed by this study's findings. Using tourniquets reduced the amount of intraoperative blood loss; however, the total amount did not differ significantly. As the operator and assistant become more skilled and the hemostatic operation becomes more mature, the amount of blood loss during the operation can be reduced and damage to the blood vessels and nerves can be avoided. Administering tranexamic acid intravenous drip before surgery has also been proven useful in numerous studies [2]; therefore, the use value of the tourniquet should be considered.

Aseptic prosthesis loosening can be diagnosed by implant displacement, bone cement fracture, and continuous radio-clear bands with widths > 2 mm at the bone-cement interface [19–21]. Currently, there is a lack of relevant literature confirming whether intraoperative tourniquets affect the medium- and long-term survival rates of prostheses. This is the first retrospective study with medium- and long-term follow-ups. TKA outcomes were evaluated primarily using Kaplan–Meier survival analysis with revision surgery as the endpoint. In contrast, short-term evaluation was based on the reconstructed lower limb contour and prosthesis placement quality [22, 23]. Joint arthroplasty can effectively reconstruct the vertical lines of the lower limbs. Theoretically, the deeper the bone cement penetrates, the better the prosthesis placement quality. Notably, some scholars have investigated whether tourniquets affect the penetration of bone cement into the bone trabeculae, but no consensus has been reached. We also discovered that some researchers' data did not truly reflect the depth of bone cement penetration in the knee prosthesis, and they measured the thickness of pure bone cement. When the bone-cement layer is too thick, stress occlusion is produced, and the local bone becomes loose, which is unconducive for long-term stability [24, 25]. Miller et al. discovered that a bone cement thickness of 3 mm achieved long-term stability of the prosthesis, whereas a thickness of < 1 mm affected the long-term survival rate of the prosthesis [4]. Hegde et al. pointed tourniquet use improves cement penetration [22]; However, Andrade et al. showed that the use of tourniquets did not affect the penetration of bone cement [26]. In this study, the anteroposterior and lateral radiographs of the knee after TKA showed that the depth of the bone cement penetration on the osteotomy surface was slightly lower in the NT group than in the T group. However, the difference was not statistically significant ($P > 0.05$).

RLL production is related to many factors, such as bone cement technology, bone cement type, type of prosthesis, and X-ray differences. Furthermore, we observed RLL occurrence at different points and found some differences, most of which were concentrated on the platform's contact surface, where prosthesis loosening was most likely to occur. There were differences at some observation points, but they were not statistically significant ($P > 0.05$). In addition, the revision rate between the two groups did not differ significantly ($P > 0.05$), indicating that tourniquet use was not directly related to the prosthetic revision rate. Ozkunt et al. discovered that the tourniquet did not affect the stability of the prosthesis within 2 years post-TKA [27]. Touzopoulos et al. tracked the occurrence of clear bands under a tibial prosthesis 3 years post-TKA, but there was no statistical difference in the stability of the prosthesis [28]. Hoffmann et al. conducted a prospective study with an average of 5.3 years and concluded that using tourniquets in TKA had no significant differences in prosthesis survival, reoperation, complications, knee function, and health status [29]. Xu conducted a 5–8-year retrospective study and discovered that using tourniquets increased the probability of RLL occurrence, but the revision rate did not differ significantly [19]. In this study, measuring the depth of bone-cement penetration in different areas around the prosthesis and the occurrence of RLL during the medium- and long-term follow-ups, with an average of 8.8 years and the longest 10.25 years showed that tourniquet use did not affect the revision rate of both groups.

This study's limitation is that the optimal time for tourniquet use (full, half, or only bone cement use) and pressure values were not included in the data. In addition, radiography was not performed by the same physician, and the radiography quality seriously affected bone cement measurement. The posterior inclination of the tibial plateau and the standard body position at the time of radiography affected the measurement of bone cement in different areas.

In summary, tourniquet use during TKA did not affect the medium- or long-term stability of knee prostheses. Improving perioperative bleeding control programs can greatly reduce the amount of intraoperative bleeding, tourniquet function can be completely replaced and tourniquet-related complications can be avoided.

Abbreviations

TKA	Total knee arthroplasty
HSS	Knee association function scores
ROM	Range of motion
ERAS	Enhanced recovery after surgery
MPTA	Medial proximal tibial angle
HKA	Hip–knee–ankle
DVT	Deep venous thrombosis
RLL	Radiolucent lines
T group	Tourniquet group
NT group	Non-tourniquet group

Supplementary statement
All methods were performed in accordance with the relevant guidelines and regulations.

Clinical trial number
Not applicable.

Authors' contributions
YY developed the idea of the study. QZ participated in its design and helped draft the manuscript. QZ, HY, RQ and TZ contributed to data acquisition and interpretation. JZ revised the manuscript. All authors have read and approved the final version of the manuscript.

Funding
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability
Data and materials supporting the conclusions of this study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Review Committee of the Second Affiliated Hospital of Anhui Medical University(YX2024-141) and designed in accordance with the Declaration of Helsinki, which waived the need for written informed consent because patients or their legal guardians, at the time of admission, signed written consent for patients' anonymized data to be analyzed and published for research purposes.

Competing interests
The authors declare no competing interests.

Received: 28 December 2024 Accepted: 20 February 2025
Published online: 27 February 2025

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