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# Comparative evaluation of surgical myocardial revascularization using autoarterial and autovenous conduits in patients with coronary artery disease: Hospital outcomes

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**Abstract:**
Objective: to evaluate the hospital outcomes of coronary artery bypass grafting using autoarterial and autovenous conduits.
Materials and Methods. We conducted a randomized clinical trial. We used the left internal thoracic artery for bypassing the anterior interventricular branch in both groups. The remaining conduits were either only the radial artery or the radial artery and great saphenous vein (study group) or solely the great saphenous vein (control group). The investigated outcomes were, among others, in-hospital mortality, Type 5 myocardial infarction, cerebrovascular event, respiratory failure, bleeding, cardiac arrhythmias, and acute kidney injury (AKI).
Results. A sample of 27 patients was randomly distributed among the study group (n=12) and the control group (n=15). According to the perioperative and early postoperative data, there were no statistically significant differences between the groups, except for the duration of stay on artificial ventilation in intensive care unit: in the study group, it was longer than in the control group: 14 (12; 18) h versus 9.3 (5.8; 13) h, p=0.034. The most common complications were cardiac arrhythmias and AKI. There were no statistically significant differences between groups regarding studied for outcomes. Postoperative hospital stay (expressed as number of bed days) also did not differ statistically significantly between groups.
Conclusion. According to our data, in the first days after surgery, the use of the radial artery does not provide significant advantages compared to the use of the great saphenous vein.

**Keywords:** coronary artery bypass grafting, arterial conduits, venous conduits, coronary artery disease, complications, cardiac surgery.

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## Introduction

Currently, coronary artery disease (CAD) dominates among all cardiovascular diseases [1]. Despite the development of medicamentous therapy and interventional treatment of CAD, in most cases, coronary artery bypass grafting (CABG) surgery remains the treatment of choice in such patients [2]. In recent years, both in Russia and worldwide, there has been an increase in the total number of CABG procedures. For example, there were 20 CABG operations conducted per 1 million population in 1997 vs. 200 per 1 million population (i.e., a tenfold increase) in 2015 [3]. These days, approximately 33 thousand CABG operations are performed annually. The contemporary level of coronary surgery allows performing CABG with low in-hospital mortality. Among the key factors influencing the effectiveness of the operation is the patency of the grafts and the durability of their functioning, which, in turn, besides the quality of the anastomosis, depends on the choice of graft material and the method of its harvesting [4]. The most commonly employed conduits are the left internal thoracic artery (LITA), the great saphenous vein (GSV), the right internal thoracic artery, and the radial artery (RA).

Numerous favorable long-term outcomes of CABG using the internal mammary artery (IMA) bypass grafting subsequently determined interest in studies of the bilateral internal mammary artery (BIMA) grafting. BIMA grafting demonstrated a higher survival rate and a reduced re-intervention rate, but was associated with a higher risk of wound complications, which was probably caused by a reduction in blood supply to the anterior chest wall [4]. However, in 2018, D.P. Taggart et al. published the results of a prospective multicenter randomized study, the Arterial Revascularization Trial (the ART), which compared groups of patients with BIMA grafting and IMA bypass grafting. The results of the analysis revealed no statistically significant differences in overall survival, incidence of myocardial infarction (MI), incidence of stroke and other cerebrovascular events, and frequencies of infectious wound complications

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between the groups of BIMA grafting and IMA bypass grafting using LITA [5].

The GSV is most commonly used as a venous conduit due to its many advantages including easy accessibility for harvesting, sufficient length for bypass grafting to any affected area, and a diameter that typically matches that of the coronary artery (CA). However, high trauma incurred in the course of GSV harvesting is a risk factor for early postoperative conduit dysfunction. According to various published sources, the patency of venous conduits, isolated by skeletonization, ranges from 70–85% one year after surgery, decreasing to under 50% after 10 years [6].

In 1973, the renowned French cardiac surgeon A. Carpentier and his colleagues were the first to use RA as an arterial conduit for CABG [7]. The RA serves as the preferred arterial conduit due to the similarity of its diameter to the CA diameter and its ability to adapt to high blood pressure, ultimately resulting in good patency in both the short and long term [8]. Several studies demonstrated that the patency of the RA at one year after the surgery ranges from 89–92% [9]. It is worth noting that an important factor for long-term functionality of the RA is a developed CA stenosis (90% or higher) and the absence of competitive blood flow [9].

The long-term functioning of conduits is a critical factor affecting the quality of life and life expectancy in a patient, especially in terms of relieving angina pectoris and preventing cardiac complications. Despite the results of studies in favor of using autoarterial conduits, venous conduits remained the most commonly used materials: there are still very few medical institutions in Russia that actively use autoarterial (except for LITA) and complete autoarterial revascularization [10]. Because a critical component of CABG surgery is the selection of an appropriate conduit, we initiated a randomized clinical trial to assess the results of using RA as a second conduit during CABG [11]. This article provides a preliminary analysis of the collected data from this study.

The objective of our study was to evaluate the results of CABG using autoarterial and autovenous conduits.

## Materials and Methods

Study design. The study protocol complied with the Declaration of Helsinki and the ethical principles of the Government of the Russian Federation regarding epidemiological research. The local Ethics Committee approved the study protocol for its compliance with international standards of good clinical practice. Prior to randomization, each patient gave written informed consent to participate in our study.

*Inclusion criteria*. The study included patients who were undergoing CABG surgery and agreed to participate in the study.

*Exclusion criteria* comprised a bypass of one coronary artery, age under 18 and over 74 years, and impossibility of using arterial and venous conduits. The use of RA is possible only if the palmar arches are intact (based on ultrasound imaging). In addition, the Allen test was used to assess the openness of the palmar arches. Other exclusion criteria involved a reduced left ventricular ejection fraction (LVEF<40%), concomitant oncological pathology, a history of oncological disease requiring radiation therapy in the chest area, previous open-heart surgery, and a concomitant pathology with a poor prognosis for the next two years.

*Randomization*. Patients who met the inclusion criteria were allocated into two groups in a 1:1 ratio by block randomization using the envelope method (with a block size of 10). The study group and the control group were assigned to arterial revascularization and venous revascularization, respectively.

*Study endpoints*. The primary endpoint of the study was in-hospital mortality. Secondary endpoints of the study included: Type 5 MI; cerebral stroke (CS) or acute cerebrovascular accident (CVA) or transient ischemic attack (TIA), respiratory failure (RF), bleeding, cardiac arrhythmias, including postoperative atrial fibrillation (POAF), acute kidney injury (AKI), general infectious complications, infectious wound complications, implantation of an electrical pacemaker, and development of a hematoma in the area of conduit harvesting.

*Identification of outcomes*. The development of Type 5 MI associated with CABG was defined sensu the third universal definition of MI [12]. CS or acute CVA or TIA was diagnosed on the basis of clinical data, results of a brain CT scan, and the conclusion of a neurologist about the complication that had occurred. RF was defined as a duration of artificial ventilation (AV) of more than 24 hours in the postoperative period. The development of POAF was stated when the following occurred: an episode with the absence of visible regular p-waves, the emergence of f-waves and irregular RR intervals on the electrocardiogram for more than 30 s or according to 24-hour Holter ECG monitoring. The development of AKI was identified according to the KDIGO criteria (Kidney Disease: Improving Global Outcomes): defined as either an increase in serum creatinine ≥0.3 mg/dL (≥26.5 mmol/L) within 48 hours or an increase ≥1.5 times of its initial value within 7 days. Bleeding was considered as acute blood loss in a patient in the early postoperative period, which required infusion of blood components (plasma or packed red blood cells).

*Surgical technique*. CABG surgery was performed both on a beating heart using the off-pump technique and under conditions of cardiopulmonary bypass (CPB) on parallel perfusion using access from a median sternotomy. The LITA was used in both groups for the anterior interventricular branch (AIVB) bypass. The remaining conduits were either the RA alone or RA and GSV (study group) or only the GSV (control group). Isolation of the RA and GSV was performed in a conventional way (*Figures 1, 2*). The RA was mainly isolated from the left upper limb. There was no bilateral RA isolation because most patients had undergone coronary angiography on their right side the day before, which was the reason for excluding this conduit from tentative use. The anastomosis with the RA was solely single; there were no sequential distal anastomoses with the RA. CPB was performed by cannulating the aorta and right sections with a two-stage cannula through the right atrial appendage. The quality of conduits (conduit bodies, anastomoses) was assessed by performing intraoperative shuntography.

*Statistical data processing*. The analyses were carried out using the STATISTICA® StatSoft and SPSS® Statistics 25.0 software packages. Data are presented as median and interquartile range, Me (Q1; Q3), and frequencies. To compare two independent samples, the Mann–Whitney U test was employed for quantitative variables, whereas the Pearson's chi-squared test was used for categorical variables. Odds ratios and 95% confidence intervals were used to assess

outcomes. The difference between groups was considered statistically significant at $p<0.05$.

## Results

Within a year from the onset of the study, we reviewed data collected from 112 patients with CAD. Based on the inclusion/exclusion criteria, 27 patients were randomized, 13 of whom were included in the study group ('arteries'), and 14 were assigned to the control group ('veins'). In one case, conversion was observed: during intraoperative shuntography, we detected the dysfunction of the arterial conduit, as a result of which it was replaced with a venous conduit. Therefore, in the end, out of 27 patients, we had 12 patients in the study group and 15 individuals in the control group.

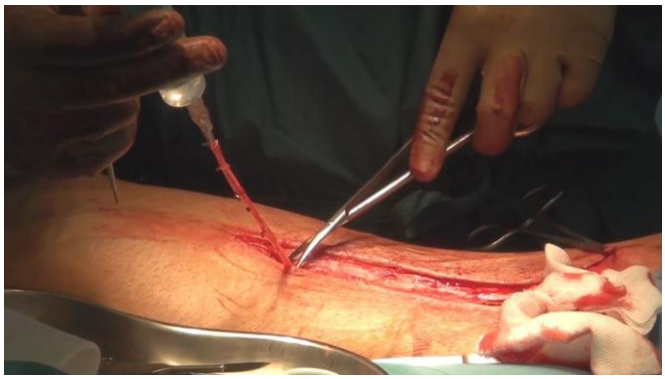

**Figure 1. Intraoperative isolation of the great saphenous vein**

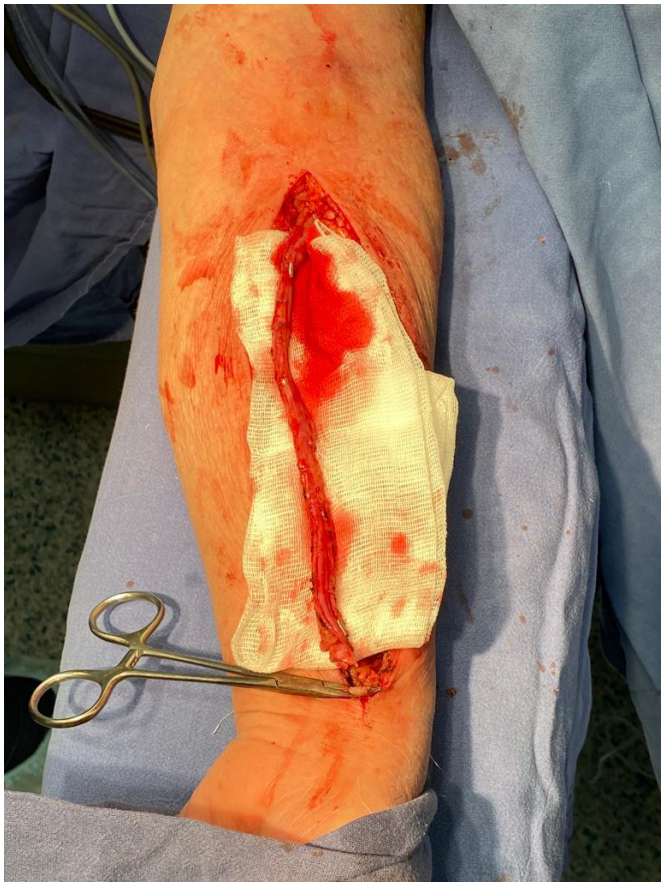

**Figure 2. Intraoperative harvesting of the radial artery for CABG**

When comparing baseline clinical, laboratory and instrumental data, as well as initial medicamentous therapy, the groups were similar and homogeneous, with the exception of BMI and the frequency of using adenosine-converting enzyme (ACE) inhibitors in the preoperative period (*Table 1*). According to the perioperative and early postoperative data, we also revealed no statistically significant differences between the groups, except for the duration of stay on AV in intensive care units. In the study group, the duration of AV was longer vs. the control group: 14 (12; 18) h versus 9.3 (5.8; 13) h, p=0.034 (*Table 2*). The postoperative hospital stay did not differ statistically significantly between the groups as well.

*Table 3* presents the studied clinical outcomes: the primary and secondary endpoints of the study. The primary endpoint rate was 0% in both groups. Besides, we observed no cases of MI, CS/acute CVA/TIA, bleeding, infectious complications or pacemaker implantation. The most common complications were cardiac arrhythmias, including POAF, and AKI. We revealed no statistically significant differences between groups for any outcome (*Table 3*).

## Discussion

This paper analyzes preliminary hospital outcomes of comparative surgical treatment of CAD using autoarterial and autovenous conduits. In addition to LITA-AIVB, the second conduit was either RA or GSV, depending on randomization. Thus, the third or higher-order conduit was always the GSV, i.e., only RA alone was used. Key baseline parameters (clinical, instrumental and laboratory) in the groups were similar (that is, they did not differ statistically significantly). Only two parameters (BMI and the frequency of using ACE inhibitors in the preoperative period) differed significantly, but given the randomized nature of the study, we regarded this as an accident. With a high degree of probability, these differences are leveled out with increasing study power, i.e., when more patients are included in the study.

We found no differences in perioperative characteristics: on average, in 90% of cases in both groups, on-pump CPB surgeries were performed. The duration of CPB was approximately 100 minutes in both groups. The total number of conduits also did not differ statistically significantly: it amounted to 2.5 (2; 3) in the study group, and 3 (2; 4) in the control group. In the early postoperative period, cardiotonic support did not differ significantly between the groups, but the duration of AV in intensive care units was higher in the arterial conduit group: 14 (12; 18) h versus 9.3 (5.8; 13) h in the control group (p=0.034). Also, we did not find statistically significant differences in the main examined events: the primary and secondary endpoints of the study. In-hospital mortality was nonexistent. The most common complications were AKI, POAF, other cardiac arrhythmias, hematomas, and RF.

The previously listed non-lethal complications (such as AKI, POAF in the early postoperative period and RF) are common complications in cardiac surgery [12–14]. The reasons for the development of these complications are varied and are mainly related to age, comorbid pathology and the extent of surgical intervention. Numerous publications suggested that when selecting a conduit for primary or subsequent myocardial revascularization, consideration must be given to its ability to function effectively over an extended period of time. Observational studies have shown that the use of RA as a secondary conduit for CABG yielded improved survival compared with GSV [12].

**Table 1. Baseline data of patients**

| Parameters | Arteries (*n*=12) | Veins (*n*=15) | *P* |
|---|---|---|---|
| Clinical data | | | |
| Age, years | 62.5 (56; 68) | 67 (58; 71) | 0.170 |
| Male gender, % | 67 | 93 | 0.082 |
| Body surface area, $m^2$ | 2.08 (1.9; 2.3) | 2.14 (2.1; 2.2) | 0.558 |
| Body mass, kg | 91 (84; 102) | 93 (85; 95) | 0.864 |
| Body mass index, units | 32.8 (30.6; 34.8) | 29.4 (27.1; 30.8) | 0.015* |
| Angina pectoris, % | 44 | 47 | 0.798 |
| Syntax Score | 30 (25; 35) | 28 (27; 31) | 0.663 |
| Diabetes, % | 33 | 33 | 1.000 |
| Chronic obstructive pulmonary disease, % | 8.3 | 0 | 0.263 |
| Arterial hypertension, % | 100 | 80 | 0.106 |
| Previous MI, % | 33 | 40 | 0.726 |
| Acute CVA/MI, % | 8.3 | 6.7 | 0.872 |
| Smoking, % | 17 | 6.7 | 0.420 |
| Echocardiography | | | |
| LVEF, % | 56 (50; 62) | 59 (55; 61) | 0.261 |
| End systolic size, mm | 3.7 (3.2; 4.4) | 3.4 (3.2; 3.6) | 0.305 |
| End diastolic size, mm | 5.4 (4.7; 6.0) | 4.9 (4.6; 5.2) | 0.146 |
| End systolic volume, mL | 49 (38; 80) | 44 (35; 51) | 0.353 |
| End diastolic volume, mL | 119 (94; 159) | 108 (88; 121) | 0.251 |
| MR grade | 1.5 (1.25; 1.75) | 1.5 (1.0; 1.5) | 0.506 |
| Laboratory data | | | |
| Leukocytes, $10^3$/μl | 8.2 (7.7; 9.2) | 6.7 (6.0; 8.3) | 0.124 |
| Hematocrit | 44 (42; 45) | 43 (39; 46) | 0.464 |
| Platelets, $10^3$/μl | 233 (185; 264) | 236 (172; 270) | 0.807 |
| Creatinine, μmol/L | 92 (75; 102) | 92 (77; 114) | 0.660 |
| Blood glucose, mmol/L | 6.4 (5.4; 7.0) | 5.7 (5; 7.5) | 0.836 |
| Potassium, mmol/L | 4.3 (3.9; 4.5) | 4.4 (4.2; 4.8) | 0.183 |
| Aspartate aminotransferase, U/L | 21 (15; 28) | 19 (16; 26) | 0.883 |
| Alanine aminotransferase, U/L | 23 (17; 33) | 21 (16; 26) | 0.608 |
| Medicamentous therapy | | | |
| β-blockers, % | 92 | 87 | 0.687 |
| Adenosine-converting enzyme inhibitors, % | 100 | 40 | 0.012* |
| Calcium channel blockers, % | 42 | 47 | 0.798 |
| Thiazide diuretic, % | 0 | 0 | – |
| Loop diuretic, % | 0 | 0 | – |
| Potassium-sparing diuretic, % | 8.3 | 13 | 0.687 |
| Nonsteroidal anti-inflammatory drugs, % | 17 | 0 | 0.106 |
| Acetylsalicylic acid, % | 17 | 20 | 0.823 |
| Other disaggregants, % | 25 | 13 | 0.446 |
| Nitrates, % | 42 | 40 | 0.931 |
| Statins, % | 100 | 83 | 0.931 |
| Low molecular weight heparin/heparin, % | 67 | 80 | 0.440 |

Syntax Score, scoring system for coronary artery lesions; CVA, cerebrovascular accident; LVEF, left ventricular ejection fraction; MI, myocardial infarction; MR, mitral regurgitation; *, the differences between the control and study groups are statistically significant.

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**Table 2. Perioperative and postoperative data**

| Parameters | Arteries (*n*=12) | Veins (*n*=15) | *P* |
|---|---|---|---|
| Cardiopulmonary bypass, % | 92 | 87 | 0.187 |
| Time of cardiopulmonary bypass, min | 95 (90; 110) | 110 (93; 127) | 0.309 |
| Anterior interventricular branch | 100 | 100 | 1.000 |
| Diagonal branch | 42 | 27 | 0.420 |
| Blunt edge branch | 33 | 60 | 0.176 |
| Enveloping branch | 17 | 47 | 0.107 |
| Intermedia | 25 | 27 | 0.923 |
| Right coronary artery | 33 | 33 | 1.000 |
| Posterior interventricular branch of the right coronary artery | 17 | 33 | 0.335 |
| Total number of conduits | 2.5 (2;3) | 3 (2;4) | 0.151 |
| Cardiotonic support, % | 83 | 80 | 0.827 |
| Adrenalin | 8.3 | 13 | |
| Norepinephrine | 58 | 73 | |
| Dopamine | 8.3 | 0 | |
| Dobutamine | 8.3 | 6.7 | |
| Artificial ventilation duration, h | 14 (12; 18) | 9.3 (5.8; 13) | 0.034* |
| Postoperative hospital stay (number of bed days) | 7 (7; 8.5) | 7 (7; 7) | 0.410 |

*, the differences between the control and study groups are statistically significant.

**Table 3. Clinical outcomes and complications**

| Outcomes | Arteries (*n*=12) | Veins (*n*=15) | OR | 95% CI | *p* |
|---|---|---|---|---|---|
| In-hospital mortality | 0 (0) | 0 (0) | – | – | – |
| Respiratory failure | 0 (0) | 6.7 | 0.360 | 0.014–9.681 | 0.543 |
| TIA | 0 (0) | 0 (0) | – | – | – |
| Bleeding | 0 (0) | 0 (0) | – | – | – |
| Arrhythmias | 1 (8.3) | 2 (13.3) | 1.182 | 0.065–21.18 | 0.909 |
| POAF | 1 (8.3) | 1 (6.7) | 1.273 | 0.071–22.72 | 0.869 |
| AKI | 1 (8.3) | 3 (20) | 0.363 | 0.032–4.035 | 0.410 |
| General infectious complications | 0 (0) | 0 (0) | – | – | – |
| Infectious wound complications | 0 (0) | 0 (0) | – | – | – |
| Pacemaker implantation | 0 (0) | 0 (0) | – | – | – |
| Hematoma | 1 (8,3) | 1 (6,7) | 1,273 | 0,071–22,72 | 0,869 |

OR, odds ratio; CI, confidence interval; TIA, transient ischemic attack; POAF, postoperative atrial fibrillation; AKI, acute kidney injury.

The use of the LITA for bypass to the AIVB is now recommended by international guidelines due to its durability: LITA patency reaches 93% 10 years after CABG surgery and 88% 15 years after it [15]. What to use as the second and third conduits is a controversial and unresolved issue to this day.

The RSVP (Radial Artery Versus Saphenous Vein Graft Patency) randomized trial was conducted to compare the 5-year patency of RA conduits with venous conduits. This study included 142 patients. After 5 years, 105 patients underwent shuntography, which showed patency of arterial conduits in 98.3% of patients vs. 86.4% of patients with GSV bypass. Stenosis was observed in 10% of patients with RA grafts, while in patients with GSV grafts, stenosis occurred in 23% of cases [16].

The Radial Artery Database International ALliance (RADIAL) project involved an analysis of patient data from five randomized clinical trials that compared the use of RA and GSV for CABG surgery. An initial report showed that RA had lower rates of mortality, MI, and repeat myocardial revascularization, compared with venous conduits at 5-year follow-up [17]. The PREVENT-IV study followed 1,923 patients who underwent CABG surgery. Of these, 117 used RA for the bypass. The incidence of arterial conduit dysfunction was 23%, which was similar ($p>0.05$) to the incidence of GSV dysfunction (25.2%) and was higher than the incidence of LITA dysfunction. Clinical outcomes such as overall mortality, MI, and repeat revascularization did not differ between the two groups. Five years after CABG, patients who underwent the bypass using the RA had similar rates of acute CVA to patients who underwent the bypass using the GSV [18].

Currently, there is a lack of large randomized trials and meta-analyses comparing the use of RA and GSV as a second and third conduits in CABG [19, 20]. Meanwhile, the majority of small clinical studies exhibited more favorable results of arterial revascularization.

Study limitations. In our opinion, this study had both strengths and weaknesses. Among limitations, we should mention weak statistical power associated with small sample sizes of both groups (study group and control group). Consequently, there was no statistical significance for the analyzed outcomes. Small sample sizes could be due to time restrictions regarding the onset of the study and the stringent inclusion and exclusion criteria, which resulted in just 27 patients recruited into the study out of a total cohort of 112 individuals over the course of a year. In this sense, continued patient recruitment is necessary to correct this particular limitation.

The strengths of the study included its prospective and randomized nature, which implied the absence of the effects of various confounding factors on the part of the surgeon making the decision on choosing a conduit. Valid factors included conducting the research within one department using one method both for performing the surgery per se and for harvesting conduits. This contributed to the formation of a more homogeneous group of patients differing solely in the types of studied conduits.

## Conclusion

Based on our preliminary analysis of collected data, we conclude that in the first days after surgery, the use of RA does not provide significant advantages compared with the use of the GSV. We did not detect statistically significant differences between the groups in the main studied events: the primary and secondary endpoints of the study. Mortality was absent. The most common complications were AKI, POAF, other cardiac arrhythmias, and RF. To obtain statistically significant results, it is necessary to continue this study using much larger samples of patients.

**Author contributions:** all authors contributed equally to the preparation of the manuscript.

**Conflict of interest.** None declared by the authors. This study has no commercial interest, as well as the interest of other legal entities or individuals.

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