Albanian Journal of Trauma and Emergency Surgery (2024) 8/1: 1381-1388
DOI: 10.32391/ajtes.v8i1.358

OPEN ACCESS JOURNALS

REVIEW ARTICLES

Emergency Treatment of Ruptured Abdominal Aneurysm

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Received: 05 October 2023 / *Accepted:* 14 November 2023 / *Published online:* 20 January 2024
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Abstract

Introduction: Abdominal aneurysm is considered a formidable pathological condition that requires prompt treatment. Its progressive increase leads to rupture and massive internal bleeding, which requires the most effective medical care. However, despite the improvement in medical equipment and postoperative care, mortality due to ruptured abdominal aneurysms is still close to 50%, which is primarily related to the severity of the pathology and open surgical intervention.

Materials and Methods: 46 patients diagnosed with rupture of the abdominal aorta took part in the study. Selection criteria were a history of abdominal aortic rupture, conservative/operative treatment for the disease, and absence of other complications (acute renal failure, liver infarction) that could affect the results of the study.

Results: Since January 2018, 46 cases of ruptured AAAs have been diagnosed. In all forty-six cases, surgical intervention was used: open surgery or endovascular technique. All 100% of patients had a previous history of diagnosed abdominal aortic aneurysm, for which they underwent periodic ultrasound examinations.

As a result of the study, it was found that endovascular aortic aneurysm correction is the optimal method for both planned and emergency treatment of aortic aneurysm and its rupture. According to the Cochrane Specialized Register, it was established that endovascular repair is associated with a reduction in early morbidity and mortality after abdominal aneurysm, compared with other methods of surgical treatment. Furthermore, the study found that, unlike open surgery methods, endovascular techniques are associated with a lower risk of complications in the form of intestinal ischemia.

Conclusions: Inferior quality studies and lack of information limit the conclusions of this review. From the statistical data shown in this paper, it can be concluded that there is a difference between endovascular and open methods of treatment of abdominal aortic aneurysm rupture. Mortality within the first 30 days after treatment and short-term complications are significantly lower in patients using EVAR. Systemic complications are also more prevalent in patients who were prescribed open surgical treatment.

Keywords: pathological condition; clinical trials; aorta; endovascular treatment; mortality.

Introduction

The abdominal aorta aneurysm (AAA) is a pathological expansion of its walls due to pressure in the vessel or structural damage, leading to blood flow disruption in the aorta and its rupture [1]. According to modern epidemiological data, this disease affects approximately 1.34% of patients [2]. The prevalence of AAA is approximately three times higher in men than in women, and the incidence increases with age and is most common between the ages of 65 and 85. The etiology of AAA is unknown, but it has been found that the risk of its occurrence increases in the presence of risk factors (smoking, obesity, stress). Furthermore, a genetic predisposition to the occurrence of aneurysm has been established [3].

Thus, it was found that the risk of AAA occurrence is considerably higher in relatives of patients with an already-diagnosed disease. In addition to that, although according to official data, the prevalence of AAA is decreasing, which is primarily associated with the improvement of the health

Original article, no submission or publication in advance or in parallel

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care system as a whole and means of prevention of risk factors for the disease (smoking, stress), a large proportion of patients is still undiagnosed, which may be related with a large proportion of asymptomatic patients, leading to the gradual expansion of the aneurysm in them and the occurrence of its rupture [4].

Thus, according to the latest data, this complication is the cause of death of about 2% of the male population aged 65-85, which substantially affects the socio-economic status of the population.

The AAA rupture is one of the most critical emergency conditions in surgery, with a mortality rate of 80-90% [5]. Recent randomized trials by *Moll F.L. et al.* [6] found that introducing annual screening among at-risk groups could reduce such a high mortality rate. Scientists found that among men, the optimal size for surgical intervention is the size of an aneurysm over 5.5 cm. However, among women, reliable data about the optimal size of AAA was not found. Even though routine screening allows the prevention of AAA rupture, treatment of the rupture itself is still a much greater concern.

In most cases, aneurysms rupture in the retroperitoneal space, which is accompanied by the classic triad of symptoms: pain, decreased arterial blood pressure (ABP), and the presence of a pulsatile mass in the retroperitoneal space. However, according to *Gibbons R.C. et al.* [7], this triad occurs only in 25-50% of patients, significantly complicating the timely diagnosis of the disease. Thus, as a rule, patients come to the emergency department with acute abdominal symptoms and hemodynamic disturbances, which significantly complicates the diagnosis and requires the latest, more effective methods of detection and management of the complication.

The primary method of treatment for rupture of the abdominal aorta is an urgent surgical intervention based on vital signs, which is practiced in most countries as an open operation. Instead, it was found that even with prompt help and successfully performed open surgery, mortality in the postoperative period reaches 50%, which is primarily associated with the severity of the patient's pathology and the operation itself. It was found that despite the improvement of medical surgical equipment and the equipment of intensive care units, the mortality rate of patients with AAA rupture in the postoperative period remained practically unchanged [8].

Recent studies by the Medical Advisory Secretariat indicate significant effectiveness of endovascular treatment methods, e.g., Endovascular Aneurysm Repair (EVAR) and Fenestrated Endovascular Aneurysm Repair (FEVAR) [9]. Previously, they were used only for planned operations for aneurysms of the abdominal aorta in its upper (FEVAR) and lower (EVAR) departments. However, according to *Tchana-Sato V. et al.* [10], endovascular methods have also proven effective for emergency surgical intervention for abdominal aorta ruptures. *Daye D. and Walker T.G.* [11] indicated that this technique is associated with significantly lower levels of intra- and postoperative complications and is also associated with a reduction in the risk of mortality in the postoperative period.

Therefore, the purpose of this study was to analyze and evaluate the advantages and disadvantages of the currently available methods of surgical treatment of abdominal aortic rupture compared with standardized open surgical interventions to optimize the treatment algorithm for this pathology further.

Materials and Methods

Forty-six patients diagnosed with rupture of the abdominal aorta took part in the study. Selection criteria were a history of abdominal aortic rupture, conservative/operative treatment for the disease, and absence of other complications (acute renal failure, liver infarction) that could affect the results of the study. During the selection of patients, such indicators as age, gender, race, smoking status, presence of hypertensive disease (HD), diabetes mellitus (DM), and coronary heart disease (CHD) in the anamnesis were considered in all patients, body weight was determined for further calculation of body mass index (BMI), as well as general blood, urine, and blood biochemistry were performed to detect the levels of leukocytes, total protein and cholesterol as prognostic markers of the occurrence of aortic aneurysm rupture and the patient's prognosis after its treatment. An initial comparative review of literary sources was conducted according to the current PRISMA recommendations [7]. This approach helped avoid inaccuracies and gave a more detailed description of the research methodology. Various aspects were considered to determine the acceptance criteria: accuracy and reliability of the results, ethics, and acceptability of the mentioned information. To ensure the high quality of the research, a generalized algorithm was developed, which included detailed instructions for the research and analysis of the results.

An analysis of sources from the Web of Science, Scopus, and PubMed databases was conducted from January 23, 2018 to June 14, 2023. At the initial stage of the study, the literature search was limited to English, German, and Albanian languages, which may have resulted in the exclusion of relevant studies by other authors in foreign languages. Broad selection criteria were deliberately chosen to include the publication in the list of reviewed articles to cover the research area more thoroughly. Publications that discussed possible treatment methods for abdominal aortic dissection in the last 5-10 years were automatically considered. Exceptional attention was paid to original clinical studies, systematic reviews, and meta-analyses, which considered and analyzed the possible risks of specific treatment methods, as well as the effectiveness of their use. For this, the search for the following indicators was used:

- primary efficacy results (number of successfully treated patients);
- mortality of patients in the first month after the surgical intervention;

- major complications (open conversion, bleeding, multiple organ failure, organ ischemia);
- complications and mortality after six months;
- the patient's quality of life after treatment.

Publications that had flaws in study design or contained more promotional material than scientific material were not considered for further analysis. This was done to avoid unreliable information or false conclusions. This approach helped increase the reliability of the results and increase their significance. The primary search terms for scientific publications and studies in this paper were the keywords listed above. A further search for each factor identified at the initial stage was performed using the terms-names of these treatment methods and their possible alternatives. The principal research models that were subject to further review and research were as follows:

- studies in which participants were divided into control and experimental groups, with a minimum number of >10 people;
- systematic reviews and meta-analyses;
- research conducted to confirm or refute possible theories of the development of biliary atresia;
- scientific publications on the study of new methods of treatment of rupture of the abdominal aorta or analysis of the effectiveness of already standardized methods.

Publications with dubious results, advertising publications, and studies without any scientific substantiation were subject to exclusion from the scientific analysis. After literature searches in databases using keywords and inclusion/exclusion criteria, 78 articles were found for the primary study. As a result, 40 publications were included in the study as literature sources.

Results

Since January 2018, 46 cases of ruptured AAAs have been diagnosed. In all forty-six cases, surgical intervention was used: open surgery or endovascular technique. All 100% of patients had a previous history of diagnosed abdominal aortic aneurysm, for which they underwent periodic ultrasound examinations.

The baseline data of patients with AAA are presented in Table 1. Notably, most patients were male and of the Caucasian race, which confirms the general data of the World Health Organization (WHO). In addition, all the subjects were older adults with a previous history of aneurysm. Thus, the average diameter of the aneurysm among the subjects was about 5 cm. Almost all subjects (85%) smoked in the past or still smoked. The body mass index for the patients varied within narrow limits, and all had excess body weight and an elevated level of total cholesterol. About half of the patients had medical conditions of coronary heart disease, hypertensive disease, or diabetes as concomitant diagnoses to the threatening condition – AAA.

In 46 cases, abdominal aortic aneurysm rupture was confirmed under various circumstances. Thus, 35 were suspected in connection with specific and characteristic complaints, 76% of all patients.

Another nine patients had a painless symptomatic picture, where aneurysm rupture was suspected but diagnosed only during planned surgical intervention. In 2 examinees, which is only 4.3%, the rupture was confirmed during the planned ultrasound examination of the aneurysm.

All 46 patients were randomized into two groups for immediate surgical intervention. In the first group of patients, an open treatment method was performed; in the second group, endovascular repositioning was performed.

Indicator	**Number, mean value (n=46)**
Age	68±2.6
Gender male	40 (87%)
Caucasian race	44 (96%)
AAA initial diameter	5.1±1.2
Smoker status:	
Current	18 (39%)
Past	21 (46%)
Never smoked	7 (15.2%)
Body mass	87.4±10.2
Body mass index	27.6±2.1
Diagnosed CHD	22 (48%)
Diagnosed HD	31 (67.4%)
Diagnosed DM	9 (19.6%)
Total cholesterol	7.8±1.1

Source: compiled by the authors.

Table 1. Initial patient data

Aneurysm of the abdominal aorta caused five fatal consequences of the intervention. 2 deaths occurred after endovascular treatment, and another 3 – in the first 24 hours after open treatment, which may have been related to the chosen technique. There were also another 12 deaths (26%) classified as sudden death due to ruptured AAA. The remaining patients (63%) survived after immediate treatment of the AAA rupture. After the surgical intervention, all patients underwent diagnostic monitoring, examination, periodic ultrasound examination, and computer tomography.

To obtain more information on the risk of repeated rupture of the aorta, the diameter of the aneurysm and its enlargement were evaluated. Depending on the size of the aneurysm, patients were divided into four groups with diameters ≤3.9 cm, from 4 to 4.9 cm, from 5 to 5.9 cm, and ≥6 cm. The first group included 17.5% of patients, followed by the second – 32.6%, the third – 28.2%, and the fourth – 21.7%. In 91.3%, the diameter of the aorta was measured during the previous 12 months.

For the rest of the cases, the last measurement was considered. Based on known aneurysm diameters, the following pattern of AAA ruptures was noted in the

categories: 5 of 8, 12 of 15, 12 of 13, and 10 of 10 ruptures in cohorts with diameters ≤3.9 cm, 4 to 4.9 cm, from 5 to 5.9 cm and ≥6 cm, respectively. Person-years were also calculated from the first AAA diameter to the last current measurement in each patient group. Thus, the number of ruptured aneurysms per 100 patient-years in the ≤3.9 cm group increased from 0.5 to 1.1, from 4 to 4.9 cm, from 1.1 to 5.9, from 5 to 5.9 cm increased from 4.8 to 6.3. Such data for patients with an aneurysm diameter ≥6 cm was not calculated due to lack of time due to the high risk of an emergency.

After emergency treatment of ruptured AAA by open or endovascular methods, it was observed that the number of postoperative deaths was almost the same (4.3% and 6.5%). Sudden deaths (26%) that were associated with aneurysm rupture occurring in the first 30 days after surgery were more common in patients who underwent open surgery (17.4% of 26%). It was also analyzed that, more often, patients after open surgery require a higher number of postoperative hospitalizations. Thus, certain advantages of endovascular technology against the classical method were found.

Compared with diagnosis by CT or ultrasound, immediate operative treatment slightly improved survival in low-risk patients with aneurysms up to 4.9 cm. Such data were obtained even though mortality after surgery was relatively low. Furthermore, in this study, there was no increase in postoperative mortality or the need for reoperation if the diameter of the abdominal aortic aneurysm was less than 5.5 cm. Such a low mortality rate compared to known figures may be related to timely diagnosis, surgeon skills, and criteria inclusions previously defined and indicated above. The results of this work indicate that there is no need for immediate surgical intervention for aneurysms up to 5.5 cm. Instead, routine diagnostics with determination of AAA diameters can prevent the development of ruptured aneurysms and the need for immediate surgical intervention.

Discussion

In this study, there was no relationship between the type of operative technique and postoperative mortality in the first 24 hours because such mortality was approximately the same in both open and endovascular patients. However, it was observed here that patients after open surgery, according to the classic Parodi method, were associated with a more frequent need for postoperative hospitalization, as well as with slightly higher rates of sudden postoperative early death in the first 30 days, which may be related to unpredictable complications.

Thus, although EVAR has been proven effective in some patients with AAA, it is only possible to indicate that it is the technique of choice for some patients because of the data obtained in this study. The use of endovascular techniques is impossible in many patients who are hemodynamically unstable due to an aneurysm or anatomical features. Indeed, some higher benefits of endovascular technology have been observed, as it is associated with lower postoperative mortality in the first 30 days and less need for prolonged hospitalization. It has been noted that both open classical *Parodi* surgery and endovascular EVAR technology are equally effective for the immediate treatment of ruptured AAAs, which was confirmed by the data of this study.

Since ancient times, the AAA has been treated exclusively by open surgery. This method of treatment was the only highly effective method, which consisted of exposing the aorta in an open method under general anesthesia, dissecting the site of the aneurysm, and replacing this area with a biosynthetic tubular graft. However, even though the complexity of this technique is impressive, along with the negative impact of surgery on the body, hemorrhages, and bleeding, the ligation of the aorta quite often leads to adverse consequences. Historically, one of the most frequent and severe complications from this operation was ischemia-reperfusion syndrome of damage to the lower part of the body. According to *Gorham T.J. et al.* [12], *Greenhalgh R.M. et al.* [13], and *Veith F.J. et al.* [14], who in their separate studies provided statistical calculations, it was concluded that due to the correct and more careful selection of patients for operative treatment and a high-quality postoperative period, the mortality rate in specialized clinics was under 2%, and in others up to 8%.

However, in the last two decades, the approach to the treatment of AAA has changed because the previous method of open surgery has been questioned due to the still high rate of complications. In parallel with this, another minimally invasive treatment method was developed – EVAR. Western scientist Parodi J. C. et al. introduced this technique into medical science in 1991 [15]. This researcher described the passage of a metal stent covered with a particular material through an aneurysm. Thus, it shut it off from the general circulation and formed a new vessel for the blood supply. The makeshift stent is delivered from an accessible distant vessel, e.g., the femoral artery. As a result of the invention of this method, with time, the results improved significantly due to the use of other types of stents, not makeshift ones, for the creation of which various commercial designs were developed, as well as updating the methods of delivering the artificial vessel to the required location [16].

After the development of this technique, most centers specializing in vascular surgery began to use EVAR to treat AAA. Early postoperative mortality and morbidity were significantly reduced (EVAR 2004). According to *Mani K. et al.* [17], since 2011, minimally invasive techniques have become the principal method of treating aneurysms. Subsequently, in 2014, a Cochrane review showed that short-term mortality after EVAR is reduced compared with medium- and long-term mortality [18].

Recently, technology has improved significantly, so stents have become even safer. Thus, modern stents are much more affordable, exist in diverse sizes and materials, and can be custom-made by adding additional structures, side windows, or branches, creating a more complex anatomical structure. This customized stent graft is delivered remotely

through an open, exposed femoral artery. Currently, such modules are described as aorto-ileal and aorto-biileal grafts with a single and bi-lumen, respectively. Due to the minimal vascular access, this minimally invasive technology can be performed under local or regional anesthesia [19].

After the invention of such a minimally invasive treatment method, large randomized controlled trials were subsequently conducted to compare the effectiveness of the two treatment methods. According to these data, a decrease in the level of complications and mortality in the early period was observed [20]. However, even though EVAR of abdominal aortic aneurysm is a newer and easier operation for the patient, it is impossible not to note that open intervention also stays practical and valuable in some instances, such as a large AAA for which it is impossible to use minimally invasive technology [21]. Furthermore, as reported in a UK study, although short-term results are positive, there is no significant difference between open and minimally invasive surgery in the context of long-term effects [22]. According to EVAR2, even the high mortality rate of patients for whom open intervention is unsuitable, even with the use of EVAR, is unlikely to change since the prognosis of such patients depends on other causes [23].

The German S3 recommendations and some research institutes recommend long-term or periodic follow-up using imaging methods after EVAR, giving preference to duplex vascular scanning or ultrasonography, which is informative and cost-effective [24, 25]. Such follow-up will allow monitoring of the patency and state of the vascular wall and planning repeated interventions, if necessary, which will reduce long-term consequences in favor of minimally invasive intervention.

Grima M.J. et al. [26], in their systematic review, which included about 14,000 patients, concluded that 42% of patients needed to follow the guidelines for postoperative follow-up by vascular surgery specialists. However, after five years of follow-up, no statistically significant difference was found between those who strictly followed the recommendations and those who did not. However, periodic imaging is necessary for EVAR patients. Thus, *Grootes I. et al.* [27] developed the Cox model, which requires intensive observation only for those with a progressive growth of an AAA of more than 1 mm per year. One year after the endovascular technique, the number of such patients reached 85%, who could be classified as at considerable risk.

Therefore, this review analyzed information from available studies with a pooled sample of more than 500 people who have been randomized to either minimally invasive or open surgery for the treatment of AAA. These studies reported short-term mortality, defined as 30-day or in-hospital mortality. No significant difference was found between the two types of operations. In general, the risks of early complications within 30 days, such as myocardial infarction, kidney complications, and respiratory failure, were assessed, after which the data were analyzed and determined to be insignificant. The only statistically confirmed and significant one was intestinal ischemia, which occurred less often during EVAR. The evidence for long-term complications at six months and one year was not statistically significant. Due to the lack of evidence, it is impossible to definitively report a significant advantage of only one treatment modality for the AAA.

There is also evidence of a particular risk of cancer with endovascular treatment. A population-based cohort study examined this risk due to the radiation dose received by the patient. Thus, those patients who underwent EVAR were exposed to a higher radiation dose due to intraoperative visualization of the stent and subsequent frequent CT angiograms [28].

Schmitz-Rixen T. et al. [29] investigated the effect of radiation on cancer risk in patients undergoing minimally invasive surgery. The data of about 14,000 patients with endovascular treatment and 24,465,000 patients with open treatment were analyzed, and the duration of observation was up to 7 years. It was noted that the risk of postoperative tumor of the abdominal cavity is higher than in patients with open surgery. However, data on overall mortality were not provided. Abdominal aneurysm rupture is a surgical emergency, so it requires urgent surgical intervention.

According to the guidelines of The Society for Vascular Surgery (SVS) and the European Society for Vascular Surgery (ESVS), endovascular surgery for the AAA was recommended [30, 31]. According to a meta-analysis by *Kontopodis N. et al.* [32], which analyzed data from 136 studies with 267,259 patients, postoperative mortality was 0.245 and 0.378 for minimally invasive and open treatment. Consequently, EVAR is associated with lower mortality.

Varkevisser R.R.B. et al. [33] showed that the 5-year survival rate of patients with open treatment is lower than with endovascular treatment. Long-term survival was significantly higher for EVAR in a late cohort of patients who underwent surgery between 2014 and 2018. However, high-quality studies are still needed to draw particular conclusions about the benefits of one or another treatment method.

This review gathered information from various sources, including meta-analyses, systematic reviews, and prospective cohort randomized trials; in a systematic review by Visser J.J. et al. [34], which included ten observational studies, none of the studies analyzed in this paper were included. Furthermore, the inclusion criteria included comparing patients after EVAR and with open interventions.

The results indicate that the odds ratio criterion varied from 0.45 to 0.67. These statistical data indicate no significant difference in using open and endovascular techniques for treating patients with the AAA; however, minimally invasive technology correlated with lower 20-day survival. Although many sources of information indicated no difference between these interventions regarding short-term mortality, a 2015 paper found a strong association between EVAR and positive postoperative outcomes [35]. Moreover, other scientists also evaluated comprehensive examinations for systemic complications after aneurysm treatment. The numbers indicated a statistically significant

association between minimally invasive endovascular surgery and fewer systemic complications compared to traditional open surgery patients [36].

A 2011 meta-analysis included a total of 42,888 patients. The population of this study was individuals with a ruptured AAA, and all participants underwent either endovascular or open surgery. However, most studies indicated no significant difference between mortality and the two types of surgery.

The study by *Takagi H. and Umemoto T.* [37] showed a close relationship between low mortality and endovascular treatment. Comparable results were confirmed in the study by *Qin C. et al.* [38], a meta-analysis that included 18 studies, 12 of which were retrospective. The rest had elements of prospective studies. This review also indicated a shorter stay for patients in the EVAR group. However, the quality of the results was heterogeneous due to the diversity of works included in this meta-analysis.

Another meta-analysis by *van Beek S.C. et al.* [39] investigated the effect of endovascular treatment on in-hospital mortality and postoperative early mortality during the first 30 days. The results were not different and showed a close correlation between reduced complications and mortality from EVAR compared to open interventions.

Antoniou G.A. et al. [40] used a random-effects model and found a statistically significant difference between lower mortality in patients with minimally invasive surgery versus open surgery (OR 0.56, 95% CI 0.5 to 0.64; P<0.001). Furthermore, this study noted a lower risk of complications in patients who underwent endovascular technology to treat the AAA. Such pathologies as respiratory complications, acute renal failure, ischemia of the lower extremities, and mesenteric ischemia occurred much less often than in those examined after open exposure to the aneurysm, according to Parodi. However, for more precise results, a prolonged study with a larger sample of patients is necessary, and thus more reliable data could be obtained.

Conclusions

Inferior quality studies and a lack of information limit the conclusions of this review. From the statistical data shown in this paper, it can be concluded that there is a difference between endovascular and open methods of treatment of abdominal aortic aneurysm rupture.

Mortality within the first 30 days after treatment and short-term complications are significantly lower in patients using EVAR. Systemic complications are also more prevalent in patients who were prescribed open surgical treatment. However, the results are still controversial. Some studies indicate no difference in the long-term survival of endovascular and open-surgery patients.

Randomized trials included in the review evaluate endovascular technology as a helpful treatment modality alongside open. Meanwhile, non-randomized studies are accumulating evidence that EVAR is the surgery of choice for most patients. However, it is also necessary to pay attention to the risk of radiation-associated cancer after minimally invasive techniques, which is associated with higher exposure. For the conclusions to be more correct, conducting randomized controlled studies with a large sample of patients is necessary. This would confirm or refute the absolute benefit of endovascular surgical intervention for abdominal aorta rupture. Limitations of this study exist due to the considerable number of excluded analyses and papers that needed to be revised by inclusion and exclusion criteria compared to other data.

Analyzing all the information that was extracted from the sources included in the list of references, it was hypothesized that EVAR treatment outcomes would improve significantly over time due to updates in treatment protocols, diagnostics, and optimization of stent grafts to restore normal blood flow through the aneurysm site. The prospects of this review are the conduct of further studies that would answer problematic questions.

COI Statement: This paper has yet to be submitted in parallel. It has yet to be fully or partially presented at a meeting, podium, or congress. It has yet to be published or submitted for consideration beforehand.

This research received no specific grant from any funding agency in the public, commercial, or non-profit sectors. There are no relevant or minor financial relationships with external companies from authors, their relatives, or next of kin.

Disclosure: The authors declared they have no conflict of interest. No funding was received for this study.

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