BMC Cardiovascular Disorders

RESEARCH

Open Access

The impact of preoperative maintaining antithrombotic therapy in patients undergoing non-coronary endovascular interventions

Jiaqi Li[1†], Linlin Fu[2†], Yepeng Zhang[1], Tong Qiao[1] and Baoyan Wang[1*]

Abstract

Background Antithrombotic medications, including antiplatelet and anticoagulant therapies, are widely used to prevent thromboembolic events in patients with cardiovascular diseases. It is common for patients on antithrombotic medications to undergo endovascular interventions though potential complications remain unclear. This study investigated the impact of continuing antithrombotic medications before endovascular interventions on perioperative clinical outcomes, particularly intraoperative blood transfusion.

Methods This retrospective cohort study included patients who underwent endovascular interventions between January 2019 and December 2022. Patients were divided into four groups based on the preoperative antithrombotic medications: (1) those not receiving any antithrombotic therapy; (2) those receiving single antiplatelet therapy; (3) those receiving dual antiplatelet therapy; (4) those receiving anticoagulant therapy. Clinical outcomes, including blood transfusion, hematoma and pseudoaneurysm, were analyzed using multivariate logistics regression. Subsequently, patients were stratified based on whether they received blood transfusion. All-cause mortality, adverse cardiovascular events and infectious events were used to evaluate the impact of blood transfusion.

Results A total of 5743 patients were included, with a mean age of 67.08 ± 14.27 years, and 69.81% of them were male. Common underlying conditions included hypertension (60.48%), vascular disease (28.75%), diabetes mellitus (22.60%), congestive heart failure (6.39%), and immune disease (4.21%). Compared to patients not receiving any antithrombotic medications, those undergoing dual antiplatelet therapy or anticoagulant therapy exhibited an increased risk of requiring blood transfusion (OR: 2.05, 95%CI: 1.30–3.23; OR: 1.92, 95%CI: 1.22–3.03). Subgroup analysis indicated that the risk of blood transfusion varied depending on the type of anesthesia, number of puncture sites and renal function, with a significant interaction ($P < 0.05$). Patients who required blood transfusion had a significantly higher rate of one-year all-cause mortality (HR: 2.18, 95% CI: 1.10–4.32) and three-month infectious events (HR: 4.92, 95% CI: 1.72–14.06).

[†]Jiaqi Li and Linlin Fu contributed equally to this work.

*Correspondence:
Baoyan Wang
wby6261275@163.com

Full list of author information is available at the end of the article

Conclusions Preoperative maintaining dual antiplatelet or anticoagulant therapy increased the risk of blood transfusion in endovascular interventions. Blood transfusion was independently associated with increased risk of all-cause mortality and infectious events. These findings suggested the need for tailored perioperative management of antithrombotic therapy in patients undergoing endovascular interventions.

Keywords Endovascular interventions, Antiplatelet therapy, Anticoagulant therapy, Blood transfusion

Introduction

Antithrombotic medications, including anticoagulants and antiplatelet agents, are widely used to prevent thrombotic events in patients with thrombotic diseases [1, 2]. Among these, anticoagulants are primarily used to reduce the risk of stroke in patients with atrial fibrillation and to prevent and treat venous thromboembolism, whereas antiplatelets are mainly indicated for the management of coronary artery disease and peripheral artery disease to prevent ischemic events. Although these medications are essential for thrombotic risk reduction, they are associated with an elevated risk of bleeding, especially during endovascular interventions [3].

Endovascular interventions have become pivotal in managing various vascular diseases, ranging from cerebrovascular disorders to peripheral artery disease, due to their minimally invasive nature, reduced trauma, shorter recovery times and lower complication risks [4, 5]. These procedures, performed within blood vessels using specialized instruments, have traditionally been classified as low bleeding risk such as coronary angiography, allowing for the continuation of antithrombotic medications perioperatively with minimal interruption [6]. However, the bleeding risk associated with various endovascular interventions appears to be related with factors such as the puncture site, vascular condition, instruments used and procedure duration [7]. For example, recent studies have indicated that arterial puncture is a high-risk bleeding procedure, with the risk significantly higher for femoral access compared to other access sites [8]. Additionally, factors such as severe renal insufficiency, coagulopathy, thrombocytopenia and advanced age may predispose patients to complications during "low-risk" vascular puncture, including persistent bleeding and hematoma formation at the puncture site. These findings highlight the complexity of bleeding risk stratification in endovascular interventions, particularly in patients receiving antithrombotic therapy.

Despite the growing number of endovascular interventions performed annually, there remains a paucity of clinical studies specifically examining the impact of preoperative maintaining antithrombotic medications on bleeding risk requiring blood transfusion. Understanding this relationship is crucial for optimizing patient outcomes. To address this gap, our study aimed to investigate this relationship, with a particular focus on its influence on perioperative blood transfusion. By analyzing data from large urban medical center, we hope to provide evidence-based insights that will inform clinical decision-making and enhance the safety and efficacy of endovascular interventions.

Methods

Study design and setting

This retrospective cohort study was conducted at Nanjing Drum Tower Hospital using original data from patients who underwent endovascular interventions between January 1, 2019, and December 31, 2022. This study was conducted in accordance with the Declaration of Helsinki. Approval for the study was obtained from the Ethics Committee of Nanjing Drum Tower Hospital (2023-117-02), and the requirement for informed consent was waived due to the retrospective nature of the study.

Inclusion and exclusion criteria

Consecutive patients undergoing endovascular interventions were identified by reviewing the hospital databases. Specific endovascular interventions referred to the procedures of percutaneous puncture under the guidance of imaging equipment, in which instruments such as puncture needles, special catheters and guide wires were introduced into the blood vessels for therapeutic purposes. The procedures (cerebrovascular interventions, aortic aneurysm repair, peripheral artery disease interventions, splanchnic artery interventions, etc.) were classified according to the international classification of diseases (ICD-10), as detailed in Supplementary Table I.

Exclusion criteria include: (1) Patients who discontinued antithrombotic medications before the procedures. (2) Patients receiving both antiplatelet and anticoagulant medications simultaneously. (3) Percutaneous coronary interventions, typically preceded by a loading dose of antiplatelet medications such as aspirin, clopidogrel and ticagrelor. (4) Endovascular interventions for angiography. (5) Endovascular interventions performed via venous access. (6) Open surgeries and endovascular interventions performed simultaneously. (7) Endovascular interventions involving the use of thrombolytic medications.

Patient cohort

The use of antithrombotic medications was carefully reviewed and documented. Based on the preoperative antithrombotic medications, patients were classified into

four groups: (1) those not receiving any antithrombotic therapy (Non-ATT). (2) those receiving single antiplatelet therapy (SAPT), such as aspirin, clopidogrel, etc. (3) those receiving dual antiplatelet therapy (DAPT), such as aspirin and clopidogrel, aspirin and ticagrelor, etc. (4) those receiving anticoagulant therapy (ACT), such as warfarin, rivaroxaban, dabigatran, etc.

Patients who had been taking antithrombotic medications did not discontinue them prior to the procedures. Generally, anesthesia was administered as either local or general based on clinical needs and procedural complexity. For patients undergoing local anesthesia, lidocaine (1–2%) was utilized at the puncture site to ensure adequate pain control. Sedative medications were administered as needed to alleviate patient anxiety. For patients requiring general anesthesia, induction was achieved using intravenous anesthetics (e.g., propofol) and analgesics (e.g., fentanyl) to induce unconsciousness, supplemented by neuromuscular blocking agents (e.g., rocuronium) to facilitate endotracheal intubation. Anesthetic depth was maintained using inhaled anesthetics (e.g., sevoflurane) or intravenous anesthetics, with mechanical ventilation provided to support respiration. Throughout the procedures, all patients were continuously monitored for hemodynamic stability, including blood pressure, heart rate, and oxygen saturation and intraoperative adjustments. For the procedures, briefly, the puncture site was identified and an incision was made to expose the vessel. Systemic heparinization was performed using heparin and the activated clotting time value was monitored to achieve approximately twice the normal value. Then the arterial sheaths were inserted via puncture in the target vessel.

Covariates

Data were collected from the electronic medical record. Extracted data included the demographic characteristics (age, gender, body mass index), comorbidities (hypertension, diabetes, vascular disease, immune disease, congestive heart failure), vascular access, number of puncture sites, sheath size, anesthesia type, duration of procedure, and laboratory indexes.

Immune disease, mainly referring to systemic vasculitis that involved the aorta and its branch arteries, can lead to wall thickening, stenosis or aneurysm of involved arteries, such as Takayasu arteritis [9]. Vascular disease, a systemic condition with atherosclerosis as the common pathological feature, can manifest as coronary artery disease, cerebrovascular disease or peripheral artery disease, etc., or a combination of two or more vascular bed diseases. Renal function was estimated by calculating estimated glomerular filtration rate (eGFR) using Cockcroft-Gault formula, with eGFR categorized into five grades: ≥90 mL/min/1.73m^2, 60–89 mL/min/1.73m^2, 30–59 mL/min/1.73m^2, 15–29 mL/min/1.73m^2 and < 15 mL/min/1.73m^2. The vascular access for endovascular intervention included femoral artery, popliteal artery, tibiofibular artery, radial artery, brachial artery, axillary artery and carotid artery. The choice of vascular access depended on various factors, including the nature of the procedure, patient anatomy and condition, physician expertise and considerations for minimizing complications. The introducer sheath was a thin, flexible tube designed to facilitate the insertion of medical instruments or devices into the body, serving as a conduit through which other tools, such as guide wire or catheter, can be safely guided into the target area. The size of an introducer sheath was determined by its diameter (French size). Anesthesia types were categorized into local and general anesthesia.

Study outcomes

The primary efficacy outcome was transfusion of whole blood or red blood cells. Indications for transfusion were determined by the attending physicians, with institutional guidelines recommended transfusion at a serum hemoglobin < 8 g/L [10]. The secondary efficacy outcomes consisted of postoperative hematoma and pseudoaneurysm at the puncture site, which were diagnosed and differentiated using ultrasound, computed tomography or magnetic resonance imaging. Hematoma, typically induced by trauma, results from the rupture of blood vessels and subsequent blood leakage into adjacent tissues, forming a coagulated mass whose size varies with the severity of the trauma and extent of hematoma. Hematoma as an outcome refers to a hematoma causing significant symptoms (e.g., persistent pain, skin ecchymosis, functional impairment) or requiring medical intervention (e.g., compression, transfusion, surgery). Pseudoaneurysm, in contrast to true aneurysms which involve permanent dilation of the vessel wall, arises from a breach in the vessel wall, causing blood to extravasate and form a sac-like structure composed of fibrous tissue and thrombosis. Clinical presentations may include pain, a pulsatile mass, or symptoms of compression on adjacent structures.

The clinical outcomes used to analyze the prognostic impact of blood transfusion were one-year all-cause mortality, one-year major adverse cardiovascular events and three-month infectious events. All-cause mortality was defined as death from any cause. Major adverse cardiovascular events (MACE) encompassed a composite of myocardial infarction, ischemic stroke, or death from cardiovascular causes. Infectious events were classified as either: (1) microbiologically defined infections (patients with a clinical syndrome and compatible microbiology result for an infection); (2) clinically defined infections (patients with a clinical syndrome consistent with

an infectious origin or etiology, but with no compatible microbiological results).

Statistical analysis

In the cohort of 5743 patients, 802 (13.96%) patients had missing data in at least one of eGFR, platelet, hemoglobin and fibrinogen. Missing data was imputed using multiple imputation by chained equations in R statistical software, resulting in multiple imputed datasets with pooled odds ratios (OR) values. The outcomes between groups were analyzed using multiple logistic regression, with the Non-ATT group serving as the reference, which were reported as OR values with corresponding 95% confidence intervals (CI). For logistic regression, we assessed the assumptions of linearity in the logit for continuous variables using the Box-Tidwell procedure. Multicollinearity was evaluated using variance inflation factors (VIF), with a threshold of VIF < 5 considered acceptable. The goodness-of-fit of the model was tested using the Hosmer-Lemeshow test. Complete data was utilized for subsequent sensitivity analysis. P-value < 0.05 was considered significant.

The risk of blood transfusion in specified subgroups was defined by age (< 70 years and ≥ 70 years), vascular disease, anesthesia type, numbers of puncture sites, sheath size (< 7 F or ≥ 7 F) and renal function (eGFR ≥ 90 mL/min/1.73m^2, eGFR 30–89 mL/min/1.73m^2 and eGFR < 30 mL/min/1.73m^2). For subgroup analysis, multivariable Cox proportional hazards regression was used to evaluate the clinical outcomes. To test for potential interactions, the interaction terms were included in the regression model to test whether the effect of the intervention differed by subgroup (subgroup × treatment) and the significance using likelihood ratio tests was assessed. The significance of interaction between antithrombotic therapies and subgroups was defined as P-for-interaction < 0.05.

To analyze the impact of blood transfusion on one-year all-cause mortality, adverse cardiovascular events and three-month infectious events, the methods of multiple imputation and inverse probability weighting were performed. The propensity score method, which simulated the effect of a randomized clinical trial in observational cohort study was used to estimate the clinical outcomes between patients who received blood transfusion and those who did not. The propensity score was calculated using logistic regression to estimate the probability of receiving antithrombotic medications based on observed covariates. Stabilized inverse probability of treatment weights (IPTW), derived from the propensity scores, was then applied to adjust for measured covariates, creating a pseudo dataset while preserving the sample size. To evaluate the performance before and after stabilized IPTW, we compared the covariates using standardized mean difference (SMD), with differences > 10% regarded as imbalanced. The covariate balances before and after IPTW were visualized using a love plot. Weighted incidence rate (IR) per 100 person-years (PY) was calculated. The risk of clinical outcomes was analyzed using survival analysis with Kaplan-Meier method and the log-rank test for univariate analysis or Cox proportional hazard regression models for multivariate analysis, expressed as hazard ratio (HR) and 95% CI.

Results

Patient characteristics

During the study period from January 2019 to December 2022, a cohort of 5743 patients undergoing endovascular interventions was analyzed (Fig. 1). The mean age of the participants was 67.08 ± 14.27 years, with male comprising 69.81% of the population. Prevalent comorbidities included hypertension (60.48%), vascular disease (28.75%), diabetes mellitus (22.60%), congestive heart failure (6.39%), and immune disease (4.21%). Baseline characteristics of the patients in each group were presented in Table 1. Generally, patients receiving antithrombotic therapy were older, had a higher proportion of comorbidities and local anesthesia. Conversely, patients not receiving antithrombotic therapy had a higher proportion of two puncture sites, upper limb or carotid artery access and abnormal laboratory indexes. Patients receiving anticoagulant therapy had the shortest duration of procedure. The application of sheath larger than 7 F was lowest in patients receiving dual antiplatelet therapy.

Clinical outcomes

The incidence rate and adjusted OR values of clinical outcomes between the groups were presented in Fig. 2. Patients receiving dual antiplatelet therapy and anticoagulant therapy had a higher risk of blood transfusion compared to those not receiving any antithrombotic medications. The highest incidence rate of blood transfusion was observed in the DAPT group (OR: 2.05, 95%CI: 1.30–3.23), followed by the ACT group (OR: 1.92, 95%CI: 1.22–3.03). The OR and 95%CI for blood transfusion among specifical antithrombotic medications compared to patients not receiving antithrombotic medication were detailed in supplementary Table II. Compared with the non-ATT group, only ACT group demonstrated an increased risk of hematoma (OR: 2.71, 95%CI: 1.20–6.13). There was no significant difference in the incidence of pseudoaneurysm between the groups. Sensitivity analysis using complete data showed results consistent with those derived from the multiple imputed datasets (Supplementary Table III).

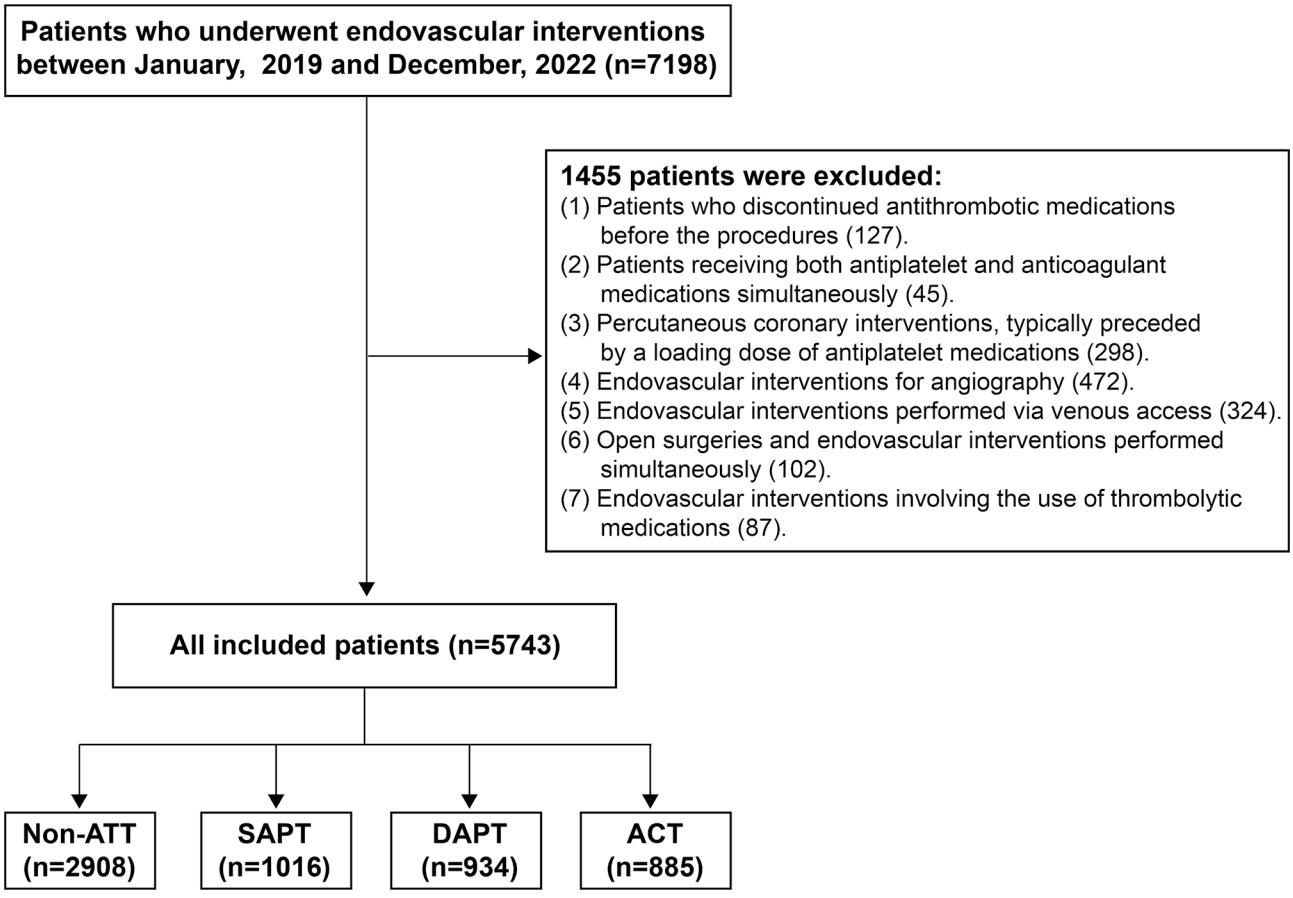

Fig. 1 The flowchart of patients included, excluded and analyzed in this study

Subgroup analysis

The results of subgroup analysis were presented in Fig. 3. When 70 years was used as a cutoff to define age subgroups, both DAPT in the subgroup of age < 70 years and ACT in the subgroup of age ≥ 70 years increased the risk of blood transfusion compared to patients not receiving antithrombotic medication. There was no evident interaction between age subgroup and antithrombotic therapies (P-for-interaction = 0.548). Although the risk of blood transfusion varied among different antithrombotic therapies in vascular disease and sheath size subgroups, no significant interactions were observed. For the anesthesia type stratification, DAPT and ACT were associated with a higher risk of blood transfusion in patients receiving local anesthesia, unlike those receiving general anesthesia (P-for-interaction < 0.001). Compared to Non-ATT group, DAPT and ACT were associated with an increased risk of blood transfusion in patients with more than three puncture sites, similar in patients with eGFR < 30 mL/min/1.73m^2. Significant interactions were noted between these subgroups and antithrombotic therapies (P-for-interaction = 0.035 or P-for-interaction = 0.014).

Impact of blood transfusion on clinical outcomes

During the hospitalization, 202 patients (3.52%) received blood transfusion. Baseline characteristics of the patients were presented in Supplementary Table IV. After IPTW, baseline characteristics of patients were well balanced between the two groups. Patients receiving blood transfusion versus those who did not, had markedly higher rates of one-year all-cause mortality (HR: 2.18, 95%CI: 1.10–4.32) and three-month infectious events (HR: 4.92, 95%CI: 1.72–14.06), while no significant differences were observed in terms of MACE (Figs. 4 and 5).

Discussion

This study highlighted the challenges and risks associated with endovascular interventions in patients receiving antithrombotic therapy. Despite the minimally invasive nature of endovascular procedures, both dual antiplatelet therapy and anticoagulant therapy increased the risk of blood transfusion in patients after adjusting for covariates such as age, comorbidities, relevant laboratory index and procedure details. Furthermore, blood transfusion was not associated with increased postoperative cardiovascular events but was linked to higher all-cause mortality and infectious complications. The study emphasized

Table 1 Baseline characteristics of patients in different groups

	Non-ATT (*n* = 2908)	SAPT (*n* = 1016)	DAPT (*n* = 934)	ACT (*n* = 885)	SMD
Age (years, %)					0.308
< 70	1764 (60.66%)	395 (38.88%)	336 (35.97%)	487 (55.03%)	
≥ 70	1144 (39.34%)	621 (61.12%)	598 (64.03%)	398 (44.97%)	
Gender (n, %)					
Male	1978 (68.02%)	758 (74.61%)	705 (75.48%)	568 (64.18%)	0.148
Female	930 (31.98%)	258 (25.39%)	229 (24.52%)	317 (35.82%)	
Body mass index (kg/m^2)	24.10 ± 3.69	23.81 ± 3.49	23.36 ± 3.49	23.76 ± 3.53	0.107
Hypertension (n, %)	1580 (54.33%)	790 (77.76%)	646 (69.16%)	458 (51.75%)	0.332
Diabetes (n, %)	396 (13.62%)	356 (35.04%)	389 (41.65%)	157 (17.74%)	0.395
Vascular disease (n, %)	421 (14.48%)	440 (43.31%)	451 (48.29%)	339 (38.31%)	0.403
Immune disease (n, %)	107 (3.68%)	50 (4.92%)	46 (4.93%)	39 (4.41%)	0.035
Congestive heart failure (n, %)	166 (5.71%)	69 (6.79%)	75 (8.03%)	57 (6.44%)	0.048
Duration of procedure (h)	1.59 ± 1.40	1.75 ± 1.35	1.57 ± 0.88	1.37 ± 1.16	0.160
Anesthesia type (n, %)					0.359
Local anesthesia	1883 (64.75%)	737 (72.54%)	831 (88.97%)	769 (86.89%)	
General anesthesia	1025 (35.25%)	279 (27.46%)	103 (11.03%)	116 (13.11%)	
Vascular access (n, %)					0.411
Femoral artery	2125 (73.07%)	908 (89.37%)	861 (92.19%)	605 (68.36%)	
Popliteal or tibiofibular artery	136 (4.68%)	25 (2.46%)	23 (2.46%)	94 (10.62%)	
Upper limb or carotid artery	647 (22.25%)	83 (8.17%)	50 (5.35%)	186 (21.02%)	
Number of puncture sites (n, %)					0.191
1	1711 (58.84%)	616 (60.63%)	595 (63.71%)	626 (70.73%)	
2	927 (31.88%)	305 (30.02%)	217 (23.23%)	166 (18.76%)	
≥ 3	270 (9.28%)	95 (9.35%)	122 (13.06%)	93(10.51%)	
Sheath size (≥ 7 F, %)	2085 (71.70%)	711 (69.98%)	565 (60.49%)	636 (71.86%)	0.127
Fibrinogen (< 2 g/L, %)	260 (9.73%)	72 (7.41%)	41 (4.65%)	75 (8.76%)	0.107
Hemoglobin (< 120 g/L, %)	1044 (36.25%)	383 (38.07%)	367 (40.02%)	369 (42.51%)	0.071
Platelet count (< 100 × 10^9/L, %)	238 (8.26%)	43 (4.27%)	27 (2.94%)	37 (4.26%)	0.118
eGFR grade (n, %)					0.176
≥ 90	1629 (61.63%)	506 (51.37%)	463 (50.71%)	459 (63.14%)	
30–89	781 (29.55%)	397 (40.31%)	395 (43.26%)	221 (30.40%)	
< 30	233 (8.82%)	82 (8.32%)	55 (6.03%)	47 (6.46%)	
Clinical outcomes					
Blood Transfusion	89 (3.06%)	32 (3.15%)	42 (4.50%)	39 (4.41%)	0.049
Hematoma	15 (0.52%)	10 (0.98%)	10 (1.07%)	12 (1.36%)	0.046
Pseudoaneurysm	11 (0.38%)	6 (0.59%)	7 (0.75%)	3 (0.34%)	0.033

the importance of individualized perioperative management of antithrombotic therapy to optimize patient outcomes.

Endovascular intervention in patients receiving antithrombotic therapy was unavoidable, but data guiding interventional physicians in the perioperative management of those patients were still limited to retrospective series primarily focused on non-interventional procedures [3]. Studies have shown that blood transfusion was independently associated with increased risk of worse clinical outcomes [11, 12]. Therefore, strict transfusion strategies and individualized antithrombotic therapy were critical for improving prognosis. Current studies on the impact of antithrombotic therapy on bleeding and blood transfusion mainly focused on surgical cardiac surgery and non-cardiac surgery. Aspirin and aspirin combined with clopidogrel increased surgical blood loss by 2.5–20% and 30–50%, respectively [13]. The addition of clopidogrel to aspirin markedly increased bleeding rates, although most studies have been conducted in the context of cardiac surgery with complete intraoperative heparinization under cardiopulmonary bypass [14]. A retrospective study has examined the effects of preoperative aspirin on bleeding and transfusion in cardiac surgery [15]. It found that in patients undergoing CABG, valve, or combined CABG/valve surgery, preoperative aspirin within 5 days of surgery was associated with an increased risk of blood transfusion. However, in non-cardiac surgery, the situation was less obvious. A Mayo Clinic study showed that in patients undergoing

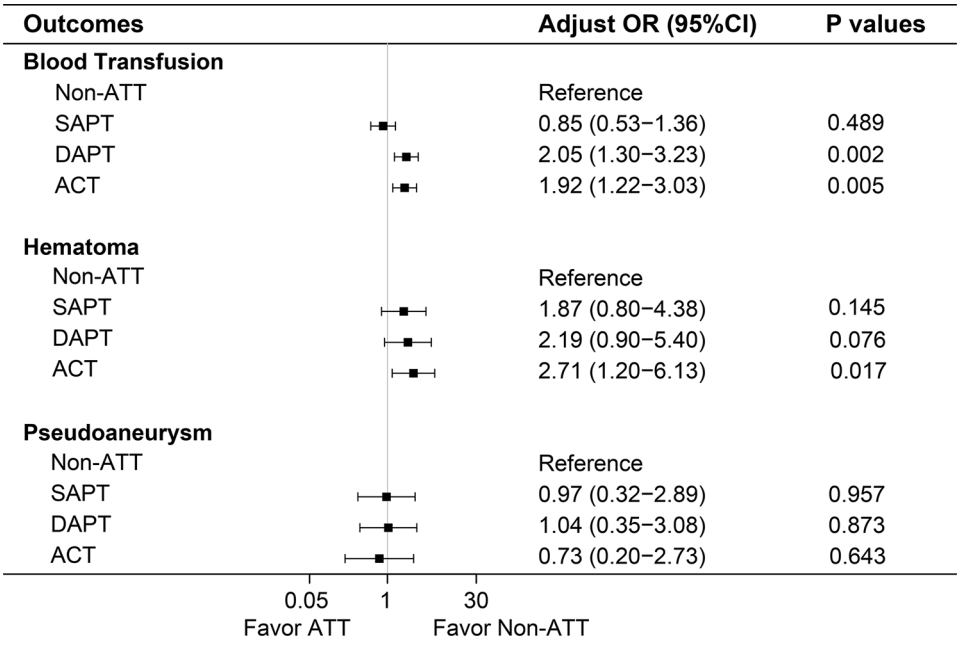

Fig. 2 Adjusted OR and 95%CI for clinical outcomes in different groups

vascular, orthopedic and visceral surgery after coronary stent implantation, the transfusion rates were 38.5% in the control group and 42.6% in the dual antiplatelet therapy group with no significant difference [16]. Anticoagulant therapy similarly increased the risk of perioperative transfusion [17, 18]. Endovascular interventional procedures, which differentiated from traditional surgical procedures, employed minimally invasive techniques. Due to the complexity of interventional procedures for aortic, peripheral and intracranial arteries, the risk of major bleeding increased, especially in procedures requiring prolonged time or involving complex vascular structures. Even then, the general consensus from the survey on perioperative use of antithrombotic medications indicated that most interventionalists did not discontinue antithrombotic medications before surgery. In our study, the disparity between these findings and the bleeding risk associated with perioperative antithrombotic medications in current open surgical procedures may be attributed to the fact that endovascular interventions cause less tissue damage, with bleeding primarily concentrated at the puncture site of the blood vessel. Although access site bleeding is the common complication of interventional procedures, it can be affected by multiple factors, including age, cardiovascular risk factors, anticoagulant/antiplatelet medications, access sites and the size of sheath [7]. Therefore, bleeding caused by the procedures may range from minor to major bleeding, potentially requiring blood transfusion.

Moreover, the blood transfusion risks of different antithrombotic therapies varied among different patient populations such as anesthesia type, number of puncture sites and eGFR grade. General anesthesia causes vasodilation, reducing blood pressure, and can also relax muscles to decrease the tension during surgical procedures. In procedures under local anesthesia, the application of anesthetics can cause vasoconstriction, thereby increasing the risk of intraoperative bleeding. Therefore, the risk of intraoperative bleeding appears to be lower with general anesthesia compared to local anesthesia [19]. The number of puncture sites required for endovascular interventional procedures depends on the type of surgery and vascular anatomy. Usually, endovascular intervention, such as common coronary angiography, only requires a single puncture in the femoral artery or radial artery. However, some interventional procedures, such as those involving the simultaneous management of multiple blood vessel branches or complex aortic stent implantation, may require multiple puncture sites, thus increasing the risk of bleeding [20]. Renal insufficiency can lead to abnormal platelet function and metabolic disorders of coagulation factors, especially in patients with uremia, who are more prone to intraoperative bleeding. Additionally, medications that are primarily eliminated by renal excretion could accumulate excessively in patients with renal insufficiency, thereby increasing the risk of bleeding [21].

Although antithrombotic therapy reduces thrombotic events and improves patient outcomes, it also increases the risk of bleeding complications, highlighting the need to balance these risks during perioperative management. In our study, although postoperative continuation

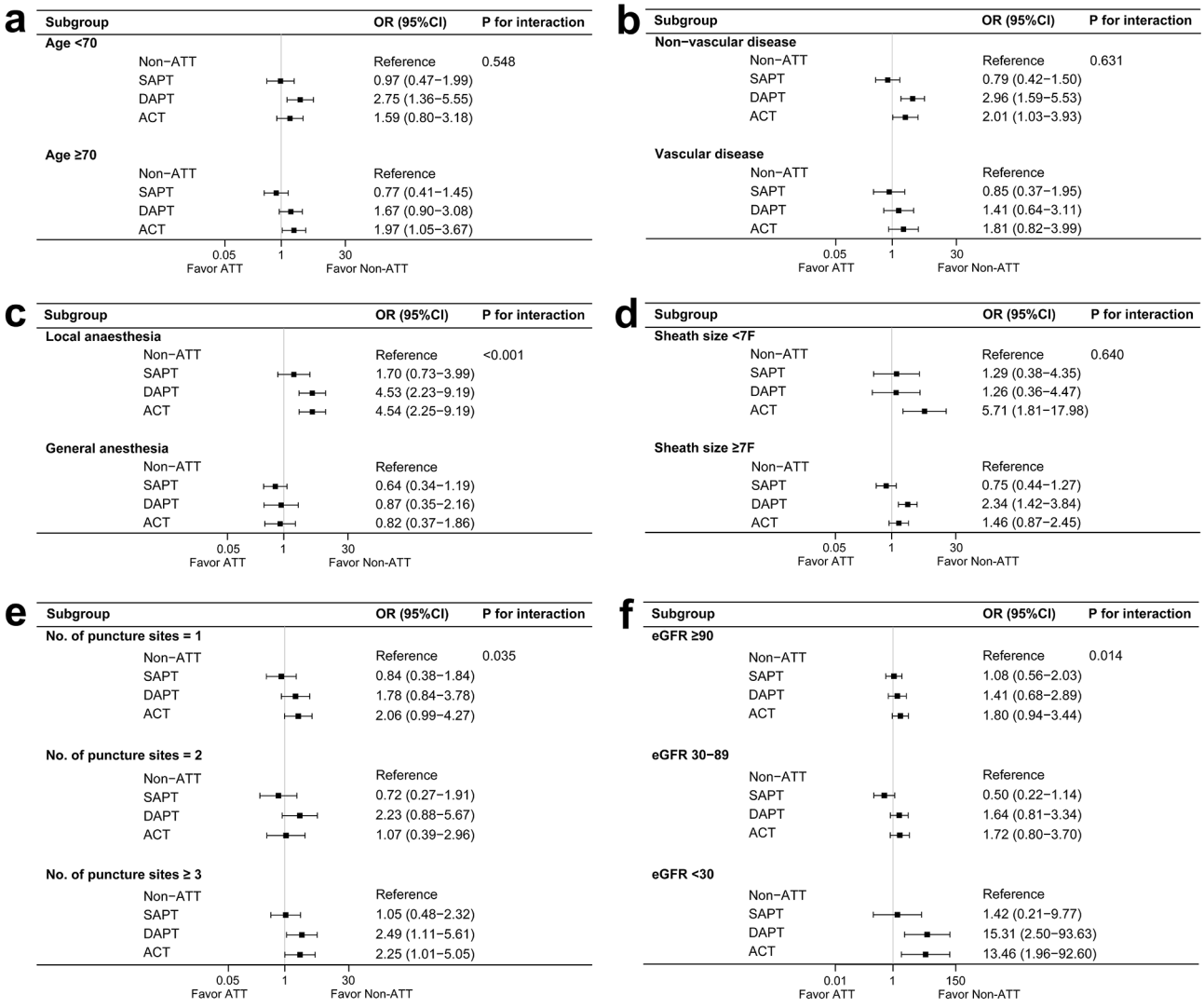

Fig. 3 The adjusted OR and 95%CI for clinical outcomes according to various subgroups in different antithrombotic groups

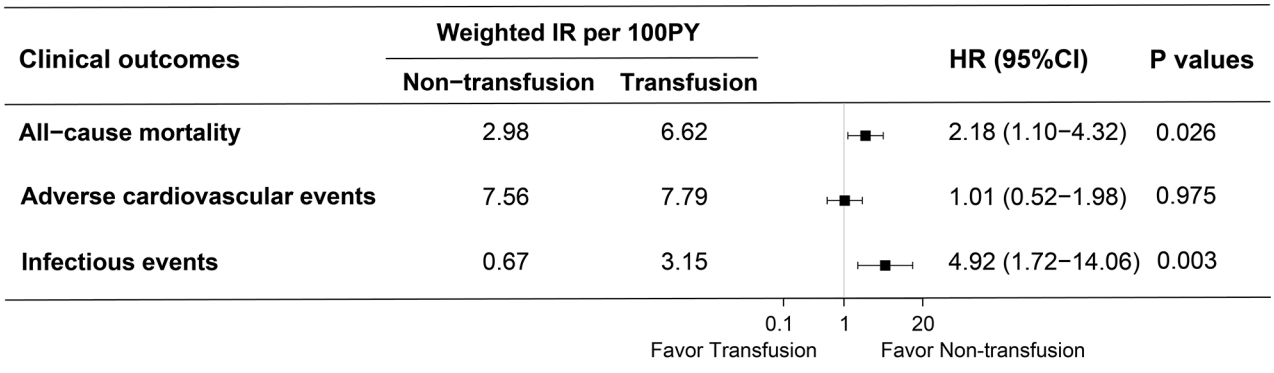

Fig. 4 Weighted IR, adjusted HR and 95%CI for clinical outcomes compared between the non-transfusion and transfusion group

of antithrombotic medications may have mitigated the association between blood transfusion and MACE, it paradoxically coincided with significantly elevated all-cause mortality and infectious complications. According to the results, antithrombotic therapy can be transiently interrupted in special patients when the thromboembolic risk is not high, especially for patients who received dual antiplatelet and anticoagulant therapy. Importantly, the

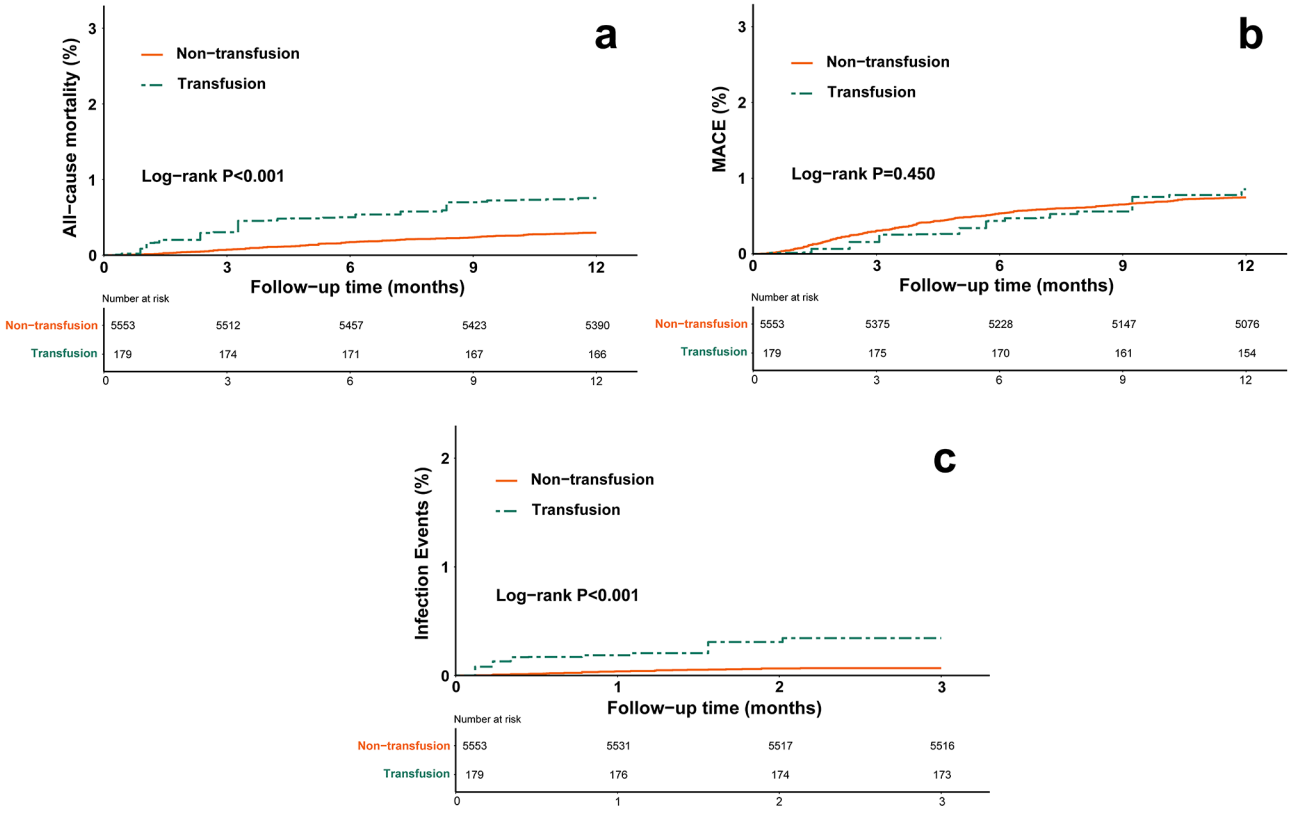

Fig. 5 The weighted cumulative incidence curves for one-year all-cause mortality (**a**), one-year MACE (**b**) and three-month infectious events (**c**) between the non-transfusion and transfusion group

assumption that endovascular interventions inherently minimize bleeding risk is misleading. Instead, individualized preoperative evaluation of procedural complexity (e.g., required puncture sites) and patient-specific factors (e.g., renal function, anesthesia type) is imperative to guide decisions on whether to discontinue antithrombotic therapy preoperatively.

The primary limitations of our study included its single-center design and retrospective nature, which may introduce potential biases and constraints in data quality and completeness. The accuracy of retrospectively collected data relied on the quality of medical records, coding practices, and documentation standards, which can vary across healthcare institutions. Additionally, our study did not assess the baseline risk of bleeding in patients prior to the procedure, it incorporated several established risk factors associated with bleeding to mitigate this limitation. On the other hand, the antithrombotic therapies were performed largely in accordance with the recent clinical guidelines. The strengths of our study included a real-world patient cohort, a large sample size, and a comprehensive overview of baseline characteristics, surgical details, and laboratory parameters.

Conclusion

This study showed that endovascular interventions, though minimally invasive, posed significant bleeding risks for patients on antithrombotic therapy. Dual antiplatelet and anticoagulant therapies independently raised blood transfusion needs, further affected by procedural complexity and patient factors. Notably, blood transfusion was linked to higher all-cause mortality and infections, despite no rise in postoperative cardiovascular events. These findings challenged the perceived safety of endovascular procedures and highlighted the need for individualized perioperative management.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12872-025-04625-8.

Supplementary Material 1

Author contributions

All authors contributed to the study conception and design. Data collection and analysis were performed by JL and LF. The first draft of the manuscript was written by JL and revised by YZ. The study was supervised by TQ and BW. All authors participated in data interpretation and manuscript review. All authors read and approved the final manuscript. JL and LF contributed equally to this work as the first author.

Funding
This study was supported by grants from the National Natural Science Foundation of China (81900427), Clinical Trials from the Affiliated Drum Tower Hospital, Medical School of Nanjing University (2021-LCYJ-PY-19).

Data availability
The data underlying this article will be shared on reasonable request to the corresponding author.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki. Approval for the study was obtained from the Ethics Committee of Nanjing Drum Tower Hospital (2023-117-02), and the requirement for informed consent was waived due to the retrospective nature of the study. All methods performed in accordance with the relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Affiliated Hospital of Medical School, Nanjing Drum Tower Hospital, Nanjing University, Nanjing, Jiangsu, China
[2]Nanjing Drum Tower Hospital, Basic Medicine and Clinical Pharmacy College, China Pharmaceutical University, Nanjing, Jiangsu, China

Received: 6 January 2025 / Accepted: 3 March 2025
Published online: 15 March 2025

References

1. Bhatia K, Ladd LM, Carr KH, Di Napoli M, Saver JL, McCullough LD, et al. Contemporary antiplatelet and anticoagulant therapies for secondary stroke prevention: a narrative review of current literature and guidelines. Curr Neurol Neurosci Rep. 2023;23(5):235–62.
2. Zywicka EM, McNally E, Elliott L, Twine CP, Mouton R, Hinchliffe RJ. Exploring the reporting standards of randomised controlled trials involving endovascular interventions for peripheral arterial disease: a systematic review. Eur J Vasc Endovasc Surg. 2024;67(1):155–64.
3. Douketis JD, Spyropoulos AC, Murad MH, Arcelus JI, Dager WE, Dunn AS, et al. Perioperative management of antithrombotic therapy: an American college of chest physicians clinical practice guideline. Chest. 2022;162(5):e207–43.
4. Isselbacher EM, Preventza O, Hamilton Black J 3rd, Augoustides JG, Beck AW, Bolen MA, et al. 2022 ACC/AHA guideline for the diagnosis and management of aortic disease: a report of the American heart association/american college of cardiology joint committee on clinical practice guidelines. Circulation. 2022;146(24):e334–482.
5. Utsunomiya M. Endovascular therapy for acute limb ischemia. J Atheroscler Thromb. 2021;28(11):1126–7.
6. Patel IJ, Rahim S, Davidson JC, Hanks SE, Tam AL, Walker TG, et al. Society of interventional radiology consensus guidelines for the periprocedural management of thrombotic and bleeding risk in patients undergoing percutaneous image-guided interventions-part II: recommendations: endorsed by the Canadian association for interventional radiology and the cardiovascular and interventional radiological society of Europe. J Vasc Interv Radiol. 2019;30(8):1168–84.
7. Mayer J, Tacher V, Novelli L, Djabbari M, You K, Chiaradia M, et al. Post-procedure bleeding in interventional radiology. Diagn Interv Imaging. 2015;96(7–8):833–40.
8. Baron TH, Kamath PS, McBane RD. Management of antithrombotic therapy in patients undergoing invasive procedures. N Engl J Med. 2013;368(22):2113–24.
9. Allan RB, Puckridge PJ, Spark JI, Delaney CL. The impact of intravascular ultrasound on femoropopliteal artery endovascular interventions: a randomized controlled trial. JACC Cardiovasc Interv. 2022;15(5):536–46.
10. Seiffert M, Conradi L, Terstesse AC, Koschyk D, Schirmer J, Schnabel RB, et al. Blood transfusion is associated with impaired outcome after transcatheter aortic valve implantation. Catheter Cardiovasc Interv. 2015;85(3):460–7.
11. Kolte D, Beale C, Aronow HD, Kennedy KF, Apostolidou E, Sellke FW, et al. Trends and outcomes of red blood cell transfusion in patients undergoing transcatheter aortic valve replacement in the united States. J Thorac Cardiovasc Surg. 2020;159(1):102–11.
12. Kwok CS, Sherwood MW, Watson SM, Nasir SB, Sperrin M, Nolan J, et al. Blood transfusion after percutaneous coronary intervention and risk of subsequent adverse outcomes: a systematic review and meta-analysis. JACC Cardiovasc Interv. 2015;8(3):436–46.
13. Mahla E, Metzler H, Bornemann-Cimenti H, Prueller F, Raggam RB, Pregartner G, et al. Platelet Inhibition and bleeding in patients undergoing non-cardiac surgery-the BIANCA observational study. Thromb Haemost. 2018;118(5):864–72.
14. Baumann Kreuziger L, Karkouti K, Tweddell J, Massicotte MP. Antithrombotic therapy management of adult and pediatric cardiac surgery patients. J Thromb Haemost. 2018;16(11):2133–46.
15. Huang JP, Donneyong M, Trivedi J, Barnard A, Chaney J, Dotson A, et al. Preoperative aspirin use and its effect on adverse events in patients undergoing cardiac operations. Ann Thorac Surg. 2015;99(6):1975–81.
16. Puelacher C, Gualandro DM, Glarner N, Lurati Buse G, Lampart A, Bolliger D, et al. Long-term outcomes of perioperative myocardial infarction/injury after non-cardiac surgery. Eur Heart J. 2023;44(19):1690–701.
17. Douketis JD, Spyropoulos AC, Anderson JM, Arnold DM, Bates SM, Blostein M, et al. The perioperative anticoagulant use for surgery evaluation (PAUSE) study for patients on a direct oral anticoagulant who need an elective surgery or procedure: design and rationale. Thromb Haemost. 2017;117(12):2415–24.
18. Boer C, Meesters MI, Veerhoek D, Vonk ABA. Anticoagulant and side-effects of Protamine in cardiac surgery: a narrative review. Br J Anaesth. 2018;120(5):914–27.
19. Kietaibl S, Ferrandis R, Godier A, Llau J, Lobo C, Macfarlane AJ, et al. Regional anaesthesia in patients on antithrombotic drugs: joint ESAIC/ESRA guidelines. Eur J Anaesthesiol. 2022;39(2):100–32.
20. Plotkin A, Ding L, Han SM, Oderich GS, Starnes BW, Lee JT, et al. Association of upper extremity and neck access with stroke in endovascular aortic repair. J Vasc Surg. 2020;72(5):1602–9.
21. Königsbrügge O, Schmaldienst S, Auinger M, Klauser-Braun R, Lorenz M, Tabernig S, et al. Antithrombotic agents for primary and secondary prevention of cardiovascular events in patients with end-stage renal disease on chronic Hemodialysis. Atherosclerosis. 2020;298:1–6.

Publisher's note