PRINciples of optimal antithrombotiC therapy and coagulation managEment during elective fenestrated and branched EndovaScular aortic repairS (PRINCE2SS)

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DELPHI CONSENSUS

Editor's Choice – PRINciples of optimal antithrombotiC therapy and coagulation managEment during elective fenestrated and branched EndovaScular aortic repairS (PRINCE^{2}SS): An International Expert Based Delphi Consensus Study

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WHAT THIS PAPER ADDS

Optimal management of antithrombotic therapy in patients scheduled for elective fenestrated branched endovascular aortic repair (F-BEVAR) is not standardised and current clinical practice guidelines do not specifically address this topic, as the published literature lacks any randomised or prospective well designed study that could reliably inform daily practice. The present international expert based Delphi consensus document details the practices endorsed at high volume aortic centres, creating the basis for future studies, and highlighting the need for dedicated reporting standards in future guidelines.

Objective: Management of antithrombotic therapy in patients undergoing elective fenestrated branched endovascular aortic repair (F-BEVAR) is not standardised, nor are there any recommendations from current guidelines. By designing an international expert based Delphi consensus, the study aimed to create recommendations on the pre-, intra-, and post-operative management of antithrombotic therapy in patients scheduled for elective F-BEVAR in high volume centres.

Methods: Eight facilitators created appropriate statements regarding the study topic that were voted on, using a four point Likert scale, by a selected panel of international experts using a three round modified Delphi consensus process. Based on the experts' responses, only those statements reaching Grade A (full agreement $\geq$ 75%) or B (overall agreement $\geq$ 80% and full disagreement $<$ 5%) were included in the final document. The round answers' consistency was graded using Cohen's k, the intraclass correlation coefficient, and, in case of double re-submission, the Fleiss k.

Results: Sixty-seven experts were included in the final analysis and voted the initial 43 statements related to pre- (n = 15), intra- (n = 10), and post-operative (n = 18) management of antithrombotic drugs. At the end of the process, six statements (13%) were rejected, 20 statements (44%) received a Grade B consensus, and 18 statements (40%) reached a Grade A consensus. Most statements (27; 71%) exhibited very high or high consistency grades, and 11 (29%) a fair or poor grading. The intra-operative statements mostly concentrated on threshold for and monitoring of proper heparinisation. The pre- and post-operative statements mainly focused on indications for dual antiplatelet therapy and its management, considering the possible need for cerebrospinal fluid drainage.

Conclusion: Based on the elevated strength and high consistency of this international expert based Delphi consensus, most of the statements might guide current clinical management of antithrombotic therapy for elective F-BEVAR. Future studies are needed to clarify the debated issues.

Keywords: Anticoagulation, Antiplatelet, Antithrombotic, Branched, Delphi, Endovascular, Fenestrated, Pararenal, Thoraco-abdominal
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INTRODUCTION

Fenestrated branched endovascular aortic repair (F-BEVAR) for complex abdominal aortic aneurysms (AAAs; e.g., short necked infra-, juxta-, or para-renal) and thoraco-abdominal aortic aneurysms (TAAAs) is a well established alternative to conventional open surgical repair in most patients with suitable anatomy (and even more so in high risk surgical candidates), and procedural and device optimisations introduced over the last decade have led to significant improvement in short term clinical success rates and midterm durability of the implanted stent grafts.[1–4] Procedural protocols have mostly been aiming to reduce the occurrence and or severity of spinal cord ischaemia (SCI) or enhance the imaging quality to speed up the procedures and reduce radiation exposure, while clinical studies have preferentially dealt with technical aspects such as analysing the results of different stent grafts for target vessel bridging.[5–8] Aortic endografts and ancillary components have been developed to reduce the rates of type I/III endoleaks and branch instability that represent the main reasons for secondary re-interventions and late aneurysm related deaths, thereby contributing to continuous improvement of outcomes over time.[9–12]

Patients planned for F-BEVAR receive different antithrombotic drugs during the phases of their therapeutic path: on admission as part of their home drug therapy regimen, intra-operatively during the procedure, and post-operatively as well as during longer term follow up. Owing to the extensive aortic coverage and involvement of critical renal and mesenteric vessels in the repair, management of antithrombotic therapy in F-BEVAR requires a careful balance between the risks and benefits of obtaining the optimal inhibition of the coagulation cascade on top of preventing serious bleeding events and minimising the rates of endoleaks and loss of target vessel patency. Nonetheless, specific antithrombotic protocols and dedicated studies are lacking in the published literature, while clinical practice guidelines from scientific societies have not specifically addressed this topic thus far.[13–17] Thus far antithrombotic management has been left to the individual centres or physicians, and details are inconsistently reported in F-BEVAR studies.[15]

By designing an international expert based Delphi consensus, the study aimed: 1) to investigate the practices endorsed at high volume aortic centres; 2) to create recommendations on pre-, intra-, and post-operative management of antithrombotic therapy in patients scheduled for elective F-BEVAR of complex AAAs and/or TAAAs; and 3) to highlight areas of uncertainty that would benefit from future research.

METHODS

Study design

A modified Delphi consensus process was used to obtain expert consensus on the pre-, intra-, and post-operative management of antithrombotic drugs in patients scheduled for elective F-BEVAR of complex AAAs and/or TAAAs. The study was designed by the University of Trieste (Italy) and Vita-Salute San Raffaele University of Milan (Italy). The acronym PRINCE^{2}SS (PRINciples of optimal antithrombotiC therapy and coagulation managEment during elective fenestrated and branched EndovaScular aortic repairS) was chosen to identify the study. All surveys were submitted online and recorded through SurveyMonkey (https://www.surveymonkey.com). Invited experts were unaware of the identity of other members of the international panel.

Core team and selection of the panel of international experts

The members of the core team were identified among the study principal investigators (authors: LB, MD, RC, SL) and three adjunctive external facilitators (authors: KM, TK, GO) were invited to join based on their expertise in the field of the consensus. To ensure proper statistical analysis, a professional biostatistician with prior experience in Delphi based research was also invited to join the core team (author: AAB). Potential international experts to be included as panel members were selected among active physicians with specialisation in vascular surgery or interventional radiology practicing in Europe, America, Asia, and Oceania. Physicians were identified based on prior publications in high rank vascular scientific journals and/or from international conference presentations on F-BEVAR procedures, and/or among researchers serving on editorial boards for peer reviewed journals relevant to the study practice. To investigate only once the endorsed practices at each aortic centre or vascular division, and avoid the potential bias derived from duplicate responses, only one physician per institution was allowed to participate in the Delphi process. The core team members were not allowed to vote but an expert colleague from their respective centre was invited to respond. To be eligible for the expert panel, physicians were required to practice in a department that had performed more than 50 endovascular aortic cases in 2019 (pre-COVID year) and had demonstrated competence as first operator with more than 25 F-BEVAR procedures during their career.

Delphi methodology

A modified Delphi method was used to construct the expert consensus.[18] To develop the initial lists of statements for expert evaluation, a preliminary exploratory questionnaire (with multiple choice questions and option for open ended suggestions) was administered to investigate the daily practice of antithrombotic drug management at each centre or division. The answers provided to the questionnaire were analysed by the core team, and statements regarding the pre-, intra-, and post-operative management of antithrombotic drugs were designed. A compressed four point Likert type scale was used to grade statements based on the level of agreement: fully agree (score 3), agree (score 2),

disagree (score 1), completely disagree (score 0). The central fifth grade of the Likert scale (e.g., "no opinion") was omitted in view of the panel expertise and based on the assumption that invited experts would be able to offer their opinion for each statement. The statements were submitted to three rounds for evaluation, and eventually modified by the core team to increase consensus according to the experts' open comments during the first two rounds. The first round was intended to submit the first formulation of the statements and collect a broad indication of the consensus strength. The second round was intended to obtain a detailed estimate of the consensus change from the original formulations to the modified formulations after they had been implemented as per the above process. The third round was intended to confirm the strength of consensus from the second to the third formulation and to confirm the statements that had failed to reach a sufficient consistency of agreement in all previous steps.

Statistical analysis, evaluation of consensus strength, and consistency of scoring

Data were analysed by a professional biostatistician as described above; all statistical analyses were carried out using R software.[19–22] The strength of consensus was classified based on the experts' responses into four categories (Table 1). In addition, the corrected mean score (range 0 − 3), assigned to each statement, with its 95% confidence interval (95% CI), the significance of the change from the previous round according to the Wilcoxon's test, and the significance of correlation with the previous rating were all evaluated. These items were used to confirm the strength of consensus considering the lower bound of the 95% CI ($>$ 2.00 to confirm strong consensus). A p value $\leq$ .025 was regarded to be a statistically significant variation, considering that a degree of multiplicity was expected.

The consistency of scoring between rounds with the proportion of agreement was estimated using the p values from Cohen's k and from the intraclass correlation coefficient (ICC) that was set for consistency using a two way model, separately between first *vs.* second and between second *vs.* third rounds. Consistency was defined as Grade I or very high if both had p value $\leq$ .001, or as Grade II or high (if p value $\leq$ .001 in one analysis and p value $\leq$ .010 in the other). The proportion of ratings exceeding the critical difference was estimated to monitor the test re-test reliability according to Bland and Altman,[23,24] and was considered as a modifier of consistency: a proportion of outliers $>$ 10% was deemed to be indicative of significant heterogeneity across experts. The Fleiss k was complemented with the estimate of the category wise k in case of statement double re-submission. Statements with a consistency Grade III or IV according to the repeated Cohen's k analysis but that otherwise resulted highly consistent according to Fleiss k, were eventually classified as Grade III.

Criteria for selection or change of statements selection

The decision to refuse or modify and resubmit a statement was taken based on a composite of different statistical criteria. The pre-defined criteria for submission or resubmission after the first round were set as follows: statements with a proportion of full disagreement $\geq$ 10% and or a mean score $<$ 2.0 were not resubmitted; all other statements were resubmitted after textual adaptations and or statements merging, as appropriate. The pre-defined criteria for submission or resubmission after the second round were set as follows:

a. statements with a proportion of overall agreement $<$ 80% and a proportion of full disagreement $>$ 5% (Grades C and D) were to be removed from the consensus.
b. statements with at least five among: a proportion of "fully agree" $>$ 75% or a proportion of overall agreement $>$ 80%, a proportion of full disagreement $<$ 5%, a mean score change from first to second round not statistically significant (Wilcoxon test − see above), a significant score correlation between first and second round, a significant measure of agreement (Cohen's k − see above), a significant intraclass correlation coefficient set for consistency, and a good test retest reliability, were to be accepted in their current form, unless suggestions from the core team recommended resubmission.

At the third and last round, only statements with grades of strength A and B were considered of sufficient quality to be included in the final set of recommendations.

Table 1. Strength and consistency grading definitions used in the development of the Delphi consensus for the recommendation of antithrombotic therapy in fenestrated and branched aortic endovascular procedures

Grade	Description	Definition
Strength grading		
A	Very strong	Full agreement $\geq$ 75%
B	Strong	Full agreement $<$ 75% Overall agreement $\geq$ 80% Full disagreement $<$ 5%
C	Fair	Full agreement $<$ 75% Overall agreement $\geq$ 80% Full disagreement $\geq$ 5%
D	Poor	Full disagreement $\geq$ 10%
Consistency grading		
I	Very high	Cohen's k and intraclass correlation coefficient, p value $\leq$ .001 in both analysis
II	High	Cohen's k and intraclass correlation coefficient, p value $\leq$ .001 in one and $\leq$ .010 in the other analysis
III	Fair	Repeated Cohen's k p value $>$ .050, Fleiss's k p value $<$ .0001
IV	Poor	Repeated Cohen's k p value $>$ .050, Fleiss's k p value $>$ .010

RESULTS

Seventy-seven experts were initially contacted and invited to participate in the PRINCE[2]SS study: 67 participants, all

meeting the pre-specified inclusion criteria, actively replied to the survey rounds (65 males, median age 49 years, IQR 43, 55) and were included in the final analysis. The experts were mainly practicing in European (66%) or North American (21%) academic or teaching hospitals (87%): 41 experts (61%) had performed more than 100 F-BEVAR cases in their career. Sixty-four experts (96%) participated in all three Delphi rounds: 65 experts in round 1, and 66 experts in rounds 2 and 3.

For the first round, the core team members designed 43 initial statements related to pre-operative ($n = 15$), intra-operative ($n = 10$), and post-operative ($n = 18$) management of antithrombotic drugs during elective F-BEVAR procedures. The history of changes from round 1 to round 3 is provided in Supplementary Table S1: after round 1, three statements were rejected, one was merged, and two new statements were created, while after round 2, three more statements were rejected.

Table 2 summarises the proportion of consensus obtained by each statement at the third round or, when not resubmitted because of the highly consistent results, at the second round. At the end of the process, six statements (13%) were rejected, 20 statements (44%) received a Grade B consensus strength, and 18 statements (40%) reached a Grade A consensus strength. The full history of strength estimates is reported in Supplementary Tables S2 and S3.

Table 3 summarises the estimates of consistency across rounds. Most statements (72%) were classified as Grade I or II, while 28% were classified as Grade III or IV. The full history of consistency estimates (Cohen's k) is reported in Supplementary Table S4. For most statements with fair or poor consistency across two rounds as evaluated with Cohen's k, the consistency was also estimated across all three rounds using the Fleiss k and the category wise k (Supplementary Table S5).

The complete text of 38 statements that received a Grade A or Grade B consensus and, in the formulation, submitted to the final round are listed in Table 4, while Supplementary Table S6 highlights the full text of the six statements that were rejected. Figures 1, 2, and 3 visually summarise a flowchart based on the final statements.

Pre-operative phase

The experts suggested (Grade A) that single antiplatelet therapy with aspirin should be considered in all cases before F-BEVAR (statement 2) and voted different dedicated statements regarding the management of anticoagulants (statements 8, 9, 11, 13). Grade B agreement was reached (statement 4) regarding the opportunity to perform elective procedures without discontinuing DAPT when a complex abdominal aneurysm repair was planned, as this would usually be considered at low risk of post-operative SCI. Conversely, two possible choices were identified with the same degree of agreement (Grade B) when a F-BEVAR would be required to treat more extensive cases at high risk of post-operative SCI (e.g., TAAA). The first scenario (statement 5) would concern cases at low risk of aneurysm rupture, in whom DAPT withdrawal might be postponed up to three months before F-BEVAR with lower cardiological risks. The second scenario (statement 6) would concern cases at high risk of aneurysm rupture, in which the planned F-BEVAR could not be postponed and therefore the procedure could be performed either withdrawing DAPT seven days before or without discontinuing DAPT but informing the patient about the potential spinal and cardiological risks.

Intra-operative phase

Experts identified different statements (16, 18, 19, 20, 21) with high strength and consistency regarding the heparin dose, the anticoagulation goal, but also how and how often to monitor the efficacy of heparinisation using the activated clotting time (ACT). The use of protamine sulphate for heparin reversal at the end of the procedure was suggested (Grade B) if the ACT was $>$ 250 seconds at the end of the procedure or when excessive bleeding or oozing from the vascular access was detected after removal of the large bore introducer sheaths (statement 22).

Post-operative phase

According to the experts' opinion, antiplatelet therapy with aspirin should be resumed within 24 hours after the F-BEVAR procedure (statements 28, 30 — Grade A). However, a more complex protocol was proposed regarding the resumption of P2Y12 inhibitors (e.g., clopidogrel), in the case of both single and dual antiplatelet therapy. The P2Y12 inhibitor should be resumed 24 — 48 hours after SCI clinical concerns have elapsed to eventually allow safe delayed CSFD placement if needed (statements 29, 30 — grade A).[16] Conversely, if the patient received a CSFD either pre-operatively or post-operatively, the P2Y12 inhibitor should be resumed 24 hours after removal of CSFD (statement 29 — Grade A; statement 31 — Grade B). The same interval was proposed for anticoagulant resumption after CSFD removal (statement 32 — Grade A). With regards to the need for antithrombotic therapy during long term follow up, there was consensus regarding the use of single antiplatelet therapy with aspirin (statement 28 — Grade A) even if the patient was under concomitant oral anticoagulant therapy (statement 37 — Grade B). On the other hand, the use of DAPT for at least one to six months after a standard F-BEVAR, or lifelong in case of small ($<$ 6 mm) and highly tortuous vessels or when long or multiple stents are employed, was more controversial (statements 38 and 45 — Grade B, consistency Grade III). Similarly, a more aggressive antithrombotic follow up regimen was advocated in the case of target vessel occlusion especially if no technical reasons for the occlusion could be demonstrated (statement 42 — Grade B).

DISCUSSION

Literature and guidelines

Despite the abundance of clinical studies on outcomes of F-BEVAR operations,[1–4,7,8] there is a striking lack of

Table 2. Strength of each individual statement in the Delphi consensus for the recommendation of antithrombotic therapy in fenestrated and branched aortic endovascular procedures

Statement	Full agreement − %	Overall agreement − %	Full disagreement − %	Mean score (95% CI)	*p* from Wilcoxon's test *	*p* from correlation *	Final strength assigned
1†	45.5	74.2	9.1	2.11 (1.87–2.35)	.39	<.001	Rejected R2
2‡	86.4	93.9	1.5	2.79 (2.64–2.93)	.25	.002	Grade A
3‡	72.7	97.0	0.0	2.70 (2.57–2.83)	.93	.48	Grade B
4†	63.6	89.4	3.0	2.50 (2.31–2.69)	.87	< .001	Grade B
5‡	63.6	89.4	1.5	2.52 (2.34–2.70)	.026	< .001	Grade B
6†	71.2	92.4	3.0	2.61 (2.43–2.78)	.34	.008	Grade B
7†	39.4	68.2	12.1	1.95 (1.70–2.21)	.006	.008	Rejected R2
8†	81.8	93.9	0.0	2.76 (2.62–2.90)	.85	< .001	Grade A
9†	72.7	92.4	3.0	2.62 (2.45–2.79)	.95	.039	Grade B
10§	38.5	63.1	15.4	N/A	N/A	N/A	Rejected R1
11‡	78.8	98.5	0.0	2.77 (2.66–2.88)	.67	.014	Grade A
12†	50.0	78.8	6.1	2.23 (2.00–2.45)	.12	.90	Rejected R2
13†	69.7	89.4	3.0	2.56 (2.38–2.75)	.87	< .001	Grade B
14‡	80.3	98.5	0.0	2.79 (2.68–2.90)	.48	< .001	Grade A
15‡	86.4	98.5	0.0	2.85 (2.75–2.95)	.56	.009	Grade A
16†	86.4	97.0	1.5	2.82 (2.69–2.94)	.11	.012	Grade A
17§	35.4	53.8	9.2	N/A	N/A	N/A	Rejected R1
18†	89.4	97.0	1.5	2.85 (2.73–2.97)	.041	< .001	Grade A
19‡	74.2	92.4	3.0	2.64 (2.47–2.81)	.15	< .001	Grade B
20‡	83.3	93.9	1.5	2.76 (2.61–2.91)	.33	< .001	Grade A
21‡	90.9	98.5	1.5	2.88 (2.77–2.99)	.71	< .001	Grade A
22†	65.2	86.4	3.0	2.48 (2.29–2.68)	.47	< .001	Grade B
23§	35.4	58.5	10.8	N/A	N/A	N/A	Rejected R1
24†	72.7	100.0	0.0	2.73 (2.62–2.84)	.47	< .001	Grade B
25‡	84.8	100.0	0.0	2.85 (2.76–2.94)	.13	< .001	Grade A
26‡	78.8	97.0	0.0	2.76 (2.64–2.88)	.19	.028	Grade A
27‡	80.3	100.0	0.0	2.80 (2.70–2.90)	.80	.003	Grade A
28‡	84.8	98.5	0.0	2.83 (2.73–2.93)	.29	< .001	Grade A
29†	81.8	93.9	1.5	2.74 (2.63–2.85)	.89	.053	Grade A
30‡	78.8	100.0	0.0	2.79 (2.69–2.89)	.24	.13	Grade A
31‡	74.2	100.0	0.0	2.74 (2.63–2.85)	.056	.041	Grade B
32‡	83.3	100.0	0.0	2.83 (2.74–2.92)	.17	.59	Grade A
33§	63.1	90.8	1.5	N/A	N/A	N/A	Merged
34‡	60.6	92.4	3.0	2.50 (2.32–2.68)	.69	< .001	Grade B
35†	71.2	95.5	3.0	2.64 (2.47–2.80)	.11	< .001	Grade B
36‡	77.3	97.0	0.0	2.74 (2.62–2.86)	.083	< .001	Grade A
37†	71.2	89.4	1.5	2.59 (2.42–2.77)	.12	< .001	Grade B
38†	57.6	84.8	3.0	2.39 (2.20–2.59)	.17	.041	Grade B
39†	65.2	90.9	1.5	2.55 (2.38–2.72)	.12	< .001	Grade B
40†	62.1	98.5	0.0	2.61 (2.48–2.73)	.43	.007	Grade B
41‡	72.7	97.0	1.5	2.68 (2.54–2.82)	.68	< .001	Grade B
42‡	74.2	98.5	0.0	2.73 (2.61–2.85)	.26	.023	Grade B
43‡	68.2	87.9	1.5	2.55 (2.37–2.73)	.92	.001	Grade B
44‡	77.3	100.0	0.0	2.77 (2.67–2.87)	.61	< .001	Grade A
45‡	56.1	92.4	1.5	2.47 (2.31–2.63)	.17	< .001	Grade B

N/A = not available.
* 64 pairs available at round 2; 65 pairs at round 3.
† Estimated at round two ($N = 66$).
‡ Estimated at round three ($N = 66$).
§ Estimated at round one ($N = 65$).

evidence and guidance, from published research as well as from society endorsed guidelines, concerning the optimal management of antithrombotic therapy in this clinical scenario which thereby remains a "grey zone" for clinical practice.[13–17] Furthermore, available studies are inconsistent in the reporting of antithrombotic protocols, and randomised controlled trials that can comprehensively cover this clinical issue, are difficult to carry out.

Pre-operative management

Summary of pre-operative management is presented in Figure 1. The main topic for debate was the choice of

Table 3. Estimates of consistency based on Cohen's k evaluation after three rounds in the Delphi consensus on antithrombotic management during fenestrated and branched endovascular aortic procedures

Statement *	Agreement − %	Cohen's k	*p*	ICC consistency (95% CI)	*p*	Test retest reliability − % †	Overall consistency
1‡	50.0	0.285	<.001	0.513 (0.308–0.673)	<.001	9.4	Rejected R2
2‖	79.7	0.331	<.001	0.385 (0.156–0.575)	<.001	4.7	Grade I
3§	67.7	0.202	.060	0.089 (-0.157–0.324)	.24	6.2	Grade IV
4‖	68.8	0.422	<.001	0.561 (0.367–0.708)	<.001	4.7	Grade I
5§	60.0	0.322	<.001	0.405 (0.180–0.589)	<.001	10.8	Grade I
6‖	65.6	0.313	.001	0.325 (0.087–0.527)	.004	6.2	Grade I
7‡	51.6	0.285	<.001	0.322 (0.084–0.525)	.005	6.2	Rejected R2
8§	86.2	0.548	<.001	0.547 (0.351–0.697)	<.001	3.1	Grade I
9‖	68.8	0.274	.005	0.255 (0.012–0.470)	.020	9.4	Grade III
10							Rejected R1
11§	76.9	0.335	.003	0.298 (0.060–0.504)	.008	4.6	Grade II
12‡	45.3	0.082	.32	-0.016 (-0.259–0.229)	.55	6.2	Rejected R2
13‖	75.0	0.470	<.001	0.568 (0.376–0.713)	<.001	4.7	Grade I
14§	80.0	0.383	<.001	0.498 (0.290–0.660)	<.001	3.1	Grade I
15§	81.5	0.195	.098	0.317 (0.081–0.519)	.005	18.5	Grade IV
16‖	79.7	0.325	<.001	0.310 (0.072–0.516)	.006	4.7	Grade I
17							Rejected R1
18‖	92.2	0.660	<.001	0.577 (0.388–0.720)	<.001	4.7	Grade I
19§	81.5	0.576	<.001	0.733 (0.597–0.828)	<.001	3.1	Grade I
20§	81.5	0.384	<.001	0.693 (0.542–0.801)	<.001	3.1	Grade I
21§	89.2	0.411	<.001	0.739 (0.605–0.832)	<.001	10.8	Grade I
22‖	68.8	0.426	<.001	0.467 (0.251–0.638)	<.001	6.2	Grade I
23							Rejected R1
24‖	78.1	0.457	<.001	0.477 (0.264–0.646)	<.001	1.6	Grade I
25§	83.1	0.460	<.001	0.469 (0.256–0.639)	<.001	16.9	Grade I
26§	75.4	0.372	<.001	0.258 (0.017–0.471)	.018	7.7	Grade III
27§	81.5	0.429	<.001	0.359 (0.128–0.553)	.002	18.5	Grade II
28§	83.1	0.417	<.001	0.439 (0.220–0.616)	<.001	1.5	Grade I
29§	75.4	0.309	.002	0.233 (-0.010–0.450)	.030	4.6	Grade III
30§	72.3	0.226	.021	0.169 (-0.077–0.395)	.088	6.2	Grade IV
31§	76.9	0.475	<.001	0.223 (-0.021–0.441)	.036	7.7	Grade III
32§	73.8	0.188	.076	0.063 (-0.182–0.301)	.31	6.2	Grade IV
33							Merged with 32
34§	64.6	0.336	<.001	0.550 (0.356–0.699)	<.001	7.7	Grade I
35‖	73.4	0.445	<.001	0.513 (0.307–0.673)	<.001	4.7	Grade I
36§	86.2	0.577	<.001	0.554 (0.361–0.702)	<.001	13.8	Grade I
37‖	65.6	0.307	<.001	0.404 (0.178–0.590)	<.001	14.1	Grade I
38‖	50.0	0.196	.023	0.256 (0.012–0.471)	.020	3.1	Grade III
39‖	65.6	0.364	<.001	0.489 (0.278–0.655)	<.001	7.8	Grade I
40‖	68.8	0.376	<.001	0.322 (0.085–0.525)	.004	3.1	Grade II
41§	81.5	0.531	<.001	0.504 (0.298–0.665)	<.001	3.1	Grade I
42§	76.9	0.308	<.001	0.274 (0.034–0.484)	.013	4.6	Grade III
43§	64.6	0.269	.003	0.397 (0.171–0.583)	<.001	9.2	Grade II
44§	80.0	0.413	<.001	0.369 (0.139–0.561)	.001	4.6	Grade I
45§	53.8	0.203	.026	0.412 (0.189–0.595)	<.001	7.7	Grade III

ICC = intraclass correlation coefficient.
* Statements 10, 17, 23, 33 were excluded at step 1; statements 44 and 45 were included at step 2.
† Proportion of cases exceeding the critical difference estimated according to Bland and Altman.
‡ Estimated at round two *vs.* 1, $N = 64$.
§ Estimated at round three *vs.* 2, $N = 65$.
‖ Accepted as final in the current form at step 2.

antithrombotic strategy in patients with cerebrospinal fluid drainage (CSFD), especially those patients receiving dual antiplatelet therapy (DAPT). A more selective use of CSFD restricted to cases at high risk of SCI (e.g., TAAA) has been advocated by an increasing number of authors, given the high rates of serious adverse events related to CSFD placement. However, CSFD remains an important rescue tool if SCI arises in the post-procedural period.[25–30] In this clinical scenario, concomitant DAPT therapy may be seen as a contraindication to CSFD placement,[16] and different recommendations were suggested by the expert panel according to the specific clinical setting of the patient, by taking into consideration the anticipated risk of SCI *vs.* the anticipated risk of withdrawing antiplatelet drugs.

Table 4. Thirty eight final grade A and B recommendations included after three rounds in the Delphi consensus on pre-operative, intra-operative, and post-operative antithrombotic management during fenestrated and branched aortic endovascular procedures

Statement	Text	Strength	Consistency
Pre-operative			
2	Single antiplatelet therapy with low dose aspirin should be considered in all patients before a planned F-BEVAR	A	I
3	Single antiplatelet therapy with P2Y12 inhibitors (e.g., clopidrogel) may be discontinued 7 d before elective F-BEVAR if CSFD is planned or may become necessary (e.g., extensive TAAA)	B	IV
4	Elective F-BEVAR planned for a complex abdominal aortic aneurysm (e.g., short necked infrarenal, juxtarenal, and pararenal, etc.) in patients with clinical indication for DAPT could be performed without discontinuing the P2Y12 inhibitor if the patient is judged to be at low risk of spinal cord ischaemia	B	I
5	Elective F-BEVAR planned for asymptomatic and low risk of rupture (e.g., < 7 cm) extensive TAAAs in patients with clinical indication for DAPT (e.g., recent DES implant) might be postponed up to three mo (AHA 2016 guidelines for non-cardiac surgery) until the P2Y12 inhibitors can be discontinued with lower risks	B	I
6	F-BEVAR planned for extensive TAAAs at high risk of rupture (e.g., symptomatic or > 7 cm) in patients with clinical indication for DAPT could be performed either withdrawing the P2Y12 inhibitors 7 d before or informing the patient about the potential risks of an urgent CSFD placement, if needed	B	I
8	Patients under VKA therapy should have the anticoagulant stopped before (with time interval for withdrawal dependent on the drug used) an elective F-BEVAR to obtain a INR < 1.2	A	I
9	Patients under DOAC therapy should have the anticoagulant stopped according to renal function: at least two d before an elective F-BEVAR if the eGFR > 30 mL/min or at least 3–5 d before if eGFR < 30 mL/min	B	III
11	VKA and DOAC therapy administered for high thrombotic risk conditions (e.g., paroxysmal atrial fibrillation, recent or recurrent DVT/PE, etc.) might be bridged with weight based and renal function adjusted LMWH (e.g., enoxaparin)	A	II
13	Basic coagulation panel (PT-INR, aPTT, platelets count, and DOAC dosage if necessary) should be obtained within 24–48 h before an elective F-BEVAR	B	I
14	Pre-operative management of antithrombotic drugs should be regulated by pre-agreed internal protocols. Multidisciplinary teams (anaesthetist, cardiologist, and/or haematologist) case discussion is selectively indicated	A	I
15	Transfemoral access, percutaneous or cut down, should not influence the pre-operative management of antithrombotic drugs	A	IV
Intra-operative			
16	Intraprocedural unfractionated heparin at the beginning of a F-BEVAR procedure should be administered with a dosage of at least 70 UI/kg and up to 100 UI/kg (=5 000–7 000 UI for a 70 kg patient) and any additional units should be administered if the ACT target is not reached	A	I
18	ACT monitoring is strongly recommended during F-BEVAR procedure, especially if the expected duration of the procedure is more than two h	A	I
19	ACT target for a F-BEVAR should be 250–300 sec	B	I
20	ACT testing is recommended at the beginning, before and after the heparinisation, regularly during (every 30–60 min), and at the end of the procedure	A	I
21	Adjunctive variable dose of unfractionated heparin might be administered during a F-BEVAR according to the ACT results to maintain the target	A	I
22	Reversal of heparinisation with protamine sulphate at the end of a F-BEVAR should be considered if ACT time > 250 sec or could be indicated in case of excessive bleeding/oozing from the vascular access	B	I
24	ROTEM/TEG test during F-BEVAR may be used in case of prolonged procedures, excessive blood loss, clinically evident bleedings, known coagulation disorders, or laboratory signs of coagulopathy	B	I
25	Intra-operative transfusion of platelets, fibrinogen, FFP, human coagulation factors or other blood derivatives (excluding PRBC) might be selectively considered based on blood test results or in case of clinically evident bleeding	A	I
Post-operative			
26	Basic coagulation panel (PT-INR, aPTT, fibrinogen, platelets count) should be performed within the initial 24 h after F-BEVAR procedure and selectively re-assessed in case of clinically evident bleedings, known coagulation disorders or laboratory signs of coagulopathy	A	III

Table 4-*continued*

Statement	Text	Strength	Consistency
27	Post-operative transfusion of platelets, fibrinogen, FFP, human coagulation factors or other blood derivatives (excluding PRBC) might be selectively considered based on blood test results and in case of clinically evident bleeding or before removing CSFD (e.g., if platelets count < 100 units × 10*9/L).	A	II
28	Single antiplatelet therapy with aspirin should be resumed or administered post-operatively within 24 h after F-BEVAR	A	I
29	Single antiplatelet therapy with P2Y12 inhibitor (e.g., clopidrogrel) might be resumed or re-administered post-operatively 24–48 h after the end of clinical concerns for potential spinal cord ischaemia and not earlier than 24 h after the CSFD removal	A	III
30	Pre-operative DAPT (e.g., recent DES implant) in case of F-BEVAR for complex abdominal aneurysms or for TAAAs without CSFD should be resumed post-operatively as follows: aspirin within 24 h and P2Y12 inhibitor 24–48 h after the end of clinical concerns for potential spinal cord ischaemia	A	IV
31	Pre-operative DAPT (i.e., recent DES implant) in case of F-BEVAR with CSFD (planned or post-operatively placed) should be resumed post-operatively as follows: aspirin within 24 h after the procedure and P2Y12 inhibitors not earlier than 24 h after the CSFD removal	B	III
32	Pre-operative DOAC or VKA therapy could be post-operatively bridged with heparin (LMVH or unfractionated) according to the underlying pathology and should be resumed not earlier than 24 h after CSFD removal	A	IV
34	Bridging therapy with either LMWH or unfractionated heparin can be administered when the CSFD is in place. LMWH should be discontinued at least 12 h and unfractionated heparin at least 2–4 h before CSFD removal	B	I
35	DVT prophylaxis with LMVH, in a patient who was not under prior VKA/DOAC therapy, should be considered until full mobilisation and at least for 24–48 h post-operatively	B	I
36	Antithrombotic drug protocols change can be re-discussed by a mutidisciplinary team in case of major/life threatening bleedings (e.g., requiring re-intervention or significant PRBC transfusions, spinal cord haematoma, renal capsula damage)	A	I
37	Single antiplatelet therapy with aspirin (or P2Y12 inhibitor) after F-BEVAR is recommended post-operatively in all patients, independently of the need for concomitant VKA/DOAC therapy	B	I
38	DAPT, in a patient not requiring concomitant VKA/DOAC therapy, may be considered post-operatively as antithrombotic therapy for at least 1–6 mo after F-BEVAR	B	III
39	P2Y12 inhibitor, as new treatment, after F-BEVAR should be initiated without a loading dose if concomitant aspirin therapy is already administered	B	I
40	When a temporary sac perfusion branch is left unbridged, the usual antithrombotic therapy should not be changed	B	II
41	The stent graft design (outer/inner branch or fenestration) should not influence the post-operative antithrombotic therapy	B	I
42	Change of the post-operative antithrombotic therapy or post-operative aggregometry or evaluation by a coagulation specialist should be considered in case of occlusion of a target vessel, especially if a morphological underlying cause cannot be demonstrated	B	III
43	Planned antithrombotic therapy should not be changed because of post-operative endoleaks	B	II
44	Antithrombotic therapy employed post-operatively and at follow up should be clearly stated in scientific papers and adequately categorised in further editions of scientific reporting standards and/or clinical practice guidelines for F-BEVAR issued by scientific societies (e.g., ESVS/SVS)	A	I
45	Post-operative lifelong DAPT could be considered when branches are mated with small (< six mm) or highly tortuous target vessels or multiple/long stents are employed	B	III

F-BEVAR = fenestrated/branched endovascular aortic repair; CSFD = cerebrospinal fluid drainage; TAAA = thoraco-abdominal aortic aneurysms; DAPT = dual antiplatelet therapy; DES = drug eluted stent; AHA = American Heart Association; VKA = vitamin K anticoagulant; DOAC = direct oral anticoagulant; eGFR = estimated glomerular filtration rate; DVT = deep venous thrombosis; PE = pulmonary embolism; LMWH = low molecular weight heparin; PT = prothrombin time; INR = International Normalised Ratio; aPTT = activated partial thromboplastin time; ACT = activated clotting time; ROTEM/TEG = rotational thromboelastrometry/thromboelastogram; FFP = frozen fresh plasma; PRBC = packed red blood cells; ESVS = European Society Vascular Surgery; SVS = Society of Vascular Surgery.

Intra-operative management

Summary of intra-operative management is presented in Figure 2. The procedural duration and demand of F-BEVAR procedures requires intra-operative anticoagulation by means of unfractionated intravenous heparin administration. In this regard, there was significant agreement among the experts on optimal practices to be endorsed. Interestingly, intra-operative transfusion of pro-thrombotic factors using ROTEM/TEG tests was suggested selectively in case of clinically evident bleeding or laboratory signs of coagulopathy (statements 24 and 25). However, its 24 hour/seven day availability in the centre was not considered mandatory.

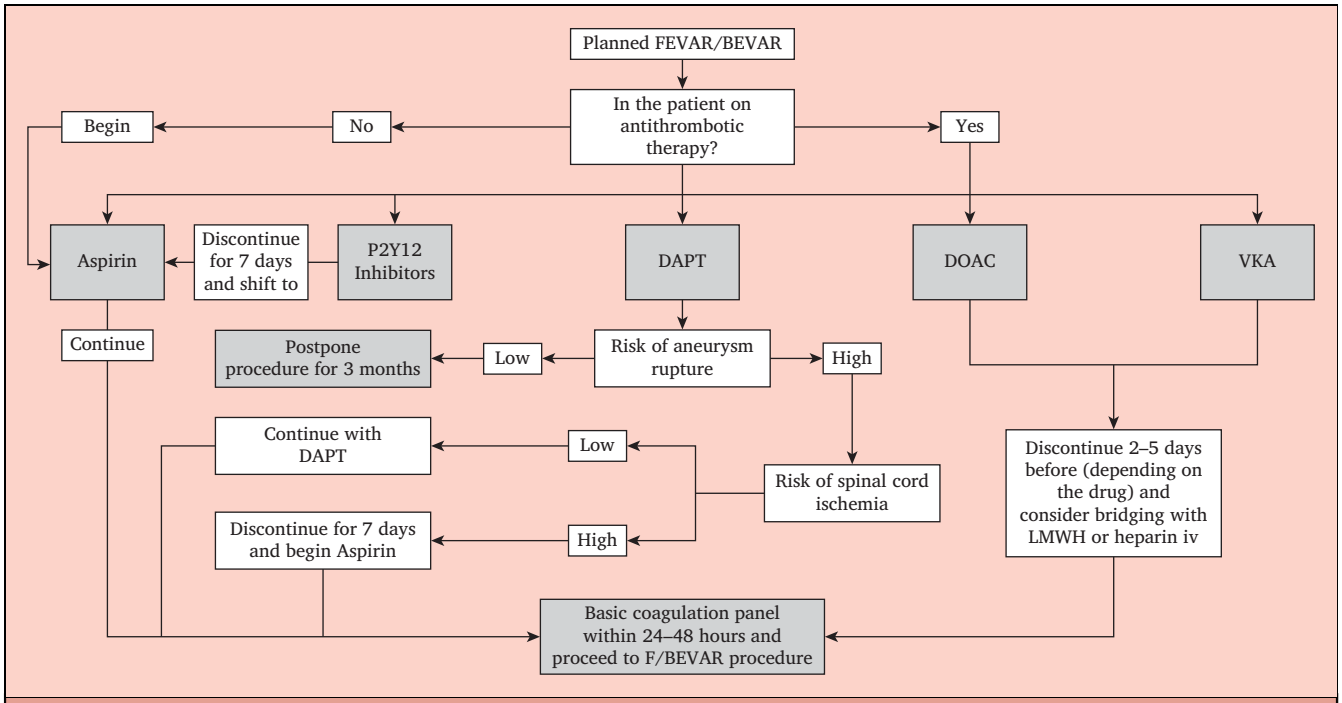

Figure 1. Flowchart of pre-operative antithrombotic drugs' management for fenestrated and branched aortic endovascular procedures summarising Delphi consensus statements 2, 3, 4, 5, 6, 8, 9, 11, 13. The strength and consistency level are listed in Table 4. DAPT = dual antiplatelet therapy; DOAC = direct oral anticoagulation; VKA = vitamin K antagonists; LMWH = low molecular weight heparin; F-BEVAR = fenestrated or branched endovascular aortic repair.

Post-operative management

Summary of post-operative management is presented in Figure 3. Most of the statements focused on the management of antithrombotic therapy during the early post-procedural phase as well as during longer term follow up. Once again, most of the consensus revolved around the optimal balance of complex antithrombotic therapy to be achieved when CSFD use is anticipated or already inserted, whether prophylactically or as a rescue manoeuvre after the onset of SCI. Interestingly, pharmacological prophylaxis of venous thromboembolism was recommended (Grade B) at least 24—48 hours post-operatively and possibly until full mobilisation (statement 35). All these protocols could be re-discussed by a multidisciplinary team in the case of major or life threatening bleeding (statement 36 — Grade A). The need for DAPT during extended follow up remained a debated issue that warrants further research.

Future perspectives

The results of this Delphi consensus highlighted a high consensus regarding different pre-, intra-, and post-operative clinical practices for management of antithrombotic therapy in patients scheduled for elective F-BEVAR.

The most critical and confounding variable was the need for pre-operative CSFD placement, or its possible post-operative use in the case of delayed SCI onset. In fact, routine prophylactic use of CSFD is a debated topic and further studies are needed to corroborate its safety and effectiveness, and to identify specific subgroups at higher risk of SCI who might benefit from pre-operative placement and therefore limit the incidence of possible associated complications with a more selective use.[31—33] Notably, guidelines regarding regional anaesthesia in patients receiving antithrombotic therapy may only serve as indirect resource for patients undergoing lumbar puncture,[16] while recommendations regarding other interventional spinal procedures in patients on antiplatelet and anticoagulant medications lack specific reporting of grading and strength owing to a lack of well designed large studies.[34] Therefore, management of this complex scenario requires a case by case basis evaluation by dedicated multidisciplinary teams involved in patient care.

The second debated issue was antithrombotic therapy to limit target vessel occlusion in the longer term: although there is a general trend towards the use of adjunctive antithrombotic drugs over single aspirin during follow up (e.g., DAPT or DOAC), there is a complete lack of evidence to support this choice and therefore, there could be attractive grounds for future clinical research studies. Overall, considering the wide lack of evidence, new clinical practice guidelines and reporting standards should include specific recommendations on antithrombotic therapy (statement 44 — Grade A).[13,14] It may also be expected that antithrombotic therapy impacts not only the overall clinical effectiveness of F-BEVAR treatment but also its cost effectiveness, which remains a debated issue in need of further research.[35]

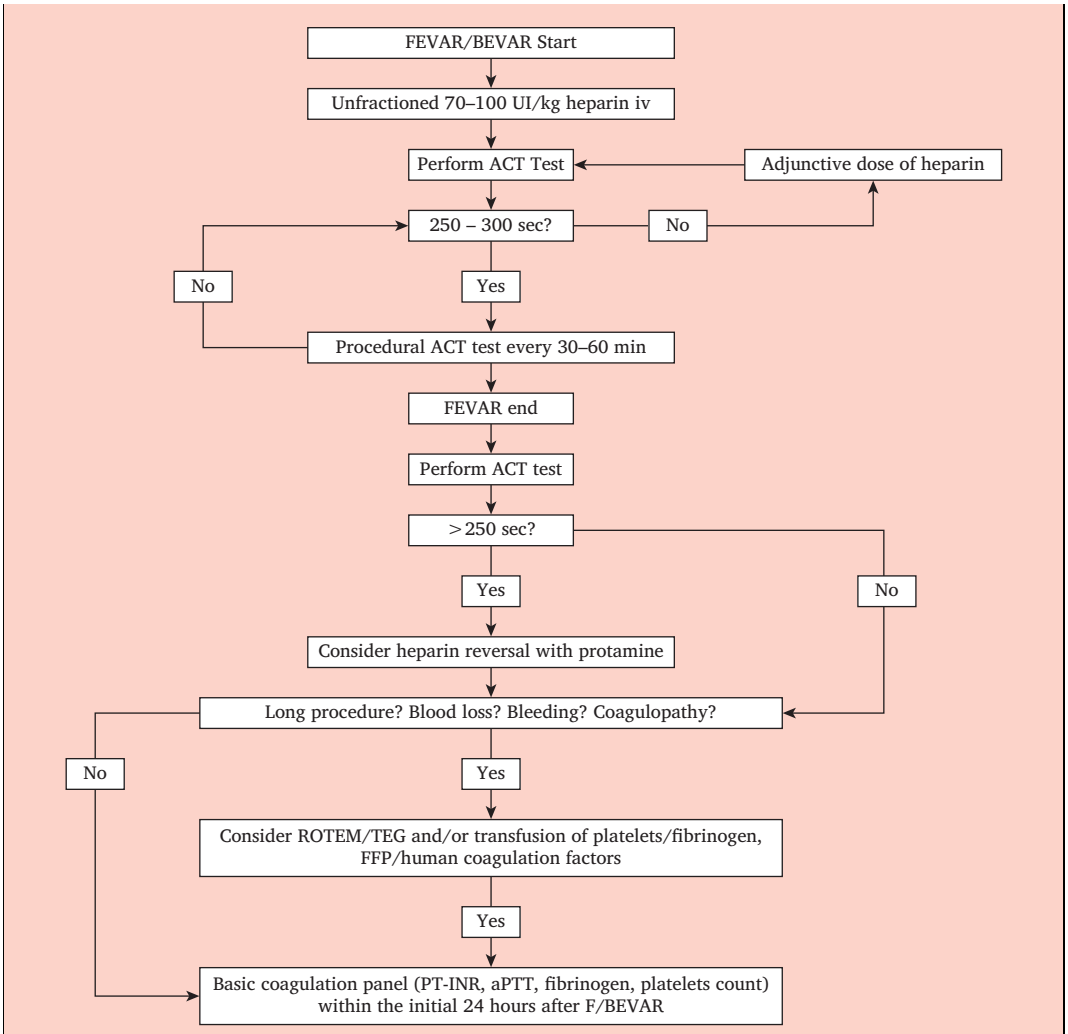

Figure 2. Flowchart of intra-operative antithrombotic drugs' management for fenestrated and branched aortic endovascular procedures summarising Delphi consensus statements 16, 18, 19, 20, 21, 22, 24, 25. The strength and consistency level are listed in Table 4. F-BEVAR = fenestrated or branched endovascular aortic repair; ACT = activated clotting time; ROTEM = rotational thromboelastrometry; TEG = thromboelastogram; FFP = frozen fresh plasma; PT-INR = prothrombin time − international normalised ratio; aPTT = activated partial thromboplastin time.

Study limitations

The findings from this study must be interpreted within the context of its limitations. First, the Delphi methodology may be subject to intrinsic shortcomings. Indeed, Delphi studies have been criticised because the included items are chosen by the researcher(s), thereby potentially introducing bias. To counteract this, the experts had the opportunity to modify and comment on statements or suggest additional ones. Second, as a random selection was not feasible, because of the experts' inclusion criteria, a pre-selected large group of international experts proposed by the core team was invited, potentially introducing selection bias as they might not fully represent real worldwide expertise, and results might also be partly influenced by local regulations and hospital policies. For instance, some geographical areas might have been under represented in spite of the international composition of the expert panel. Third, the strength of consensus among experts is often considered to represent the same level of evidence as literature based guidelines, although this might not necessarily hold true because guidelines, which are graded with a definition of strength recommendations, are based on literature analysis whereas consensus deriving from the Delphi process can only be indicative of good practice hints. Although some statements did not reach sufficient consensus and were rejected from the final formulation, this may not be equivalent to the assumption they would not address clinically relevant questions. Therefore, consensus statements should only be considered as evidence in progress to be further investigated and confirmed by clinical studies, if

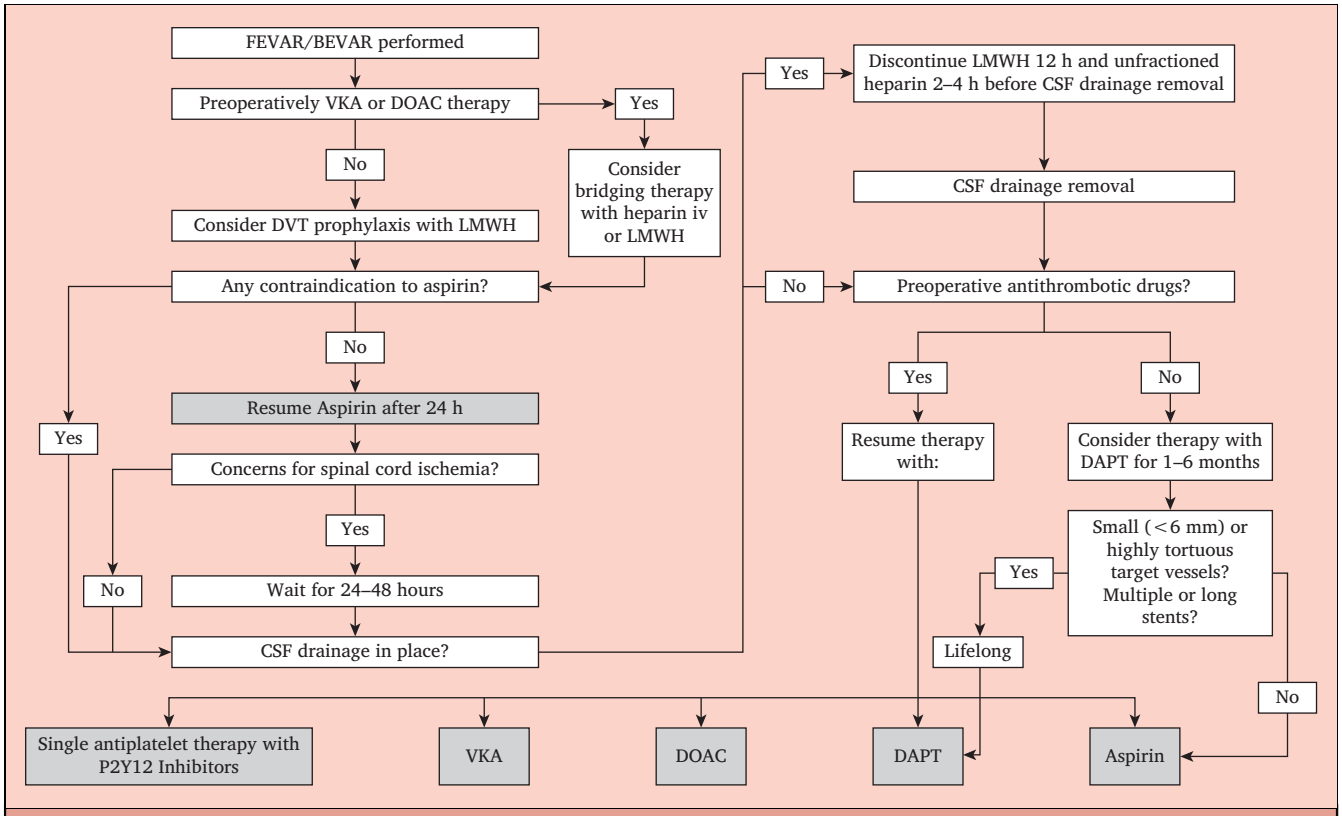

Figure 3. Flowchart of post-operative antithrombotic drugs' management for fenestrated and branched aortic endovascular procedures summarising Delphi consensus statements 28, 29, 30, 31, 32, 34, 35, 37, 38. The strength and consistency level are listed in Table 4. DAPT = dual antiplatelet therapy; DOAC = direct oral anticoagulation; VKA = vitamin K antagonists; LMWH = low molecular weight heparin; F-BEVAR = fenestrated or branched endovascular aortic repair; DVT = deep venous thrombosis; CSF = cerebrospinal fluid.

possible, and need to be implemented in daily practice with proper clinical judgement. To mitigate this limitation, whenever present, clinical practice guidelines from recognised scientific societies were consulted to ensure proposed statements would not be discordant.[13,15–17] Lastly, it should be borne in mind that consensus documents may be as accurate as the supporting evidence coming from available literature and clinical practice, therefore the need to update this work in coming years might arise in order to reflect future developments and further advances in knowledge and technique.

Conclusion

Most statements regarding the pre-, intra-, and post-operative management of antithrombotic drugs in patients undergoing elective F-BEVAR reached an elevated strength of consensus and high consistency of the formulation; therefore, they might serve as guidance for daily clinical practice. Future studies are needed to clarify debated issues such as optimal practices in patients receiving cerebrospinal fluid drainage or the need for and duration of dual antiplatelet therapy during follow up. Clinical practice guidelines and reporting standards should incorporate dedicated statements that can guide clinicians in decision making.

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CONFLICT OF INTEREST STATEMENT AND FUNDING

None

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2022.03.002.

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COUP D'OEIL

An Unorthodox Vascular Surgical Approach to Save a Limb

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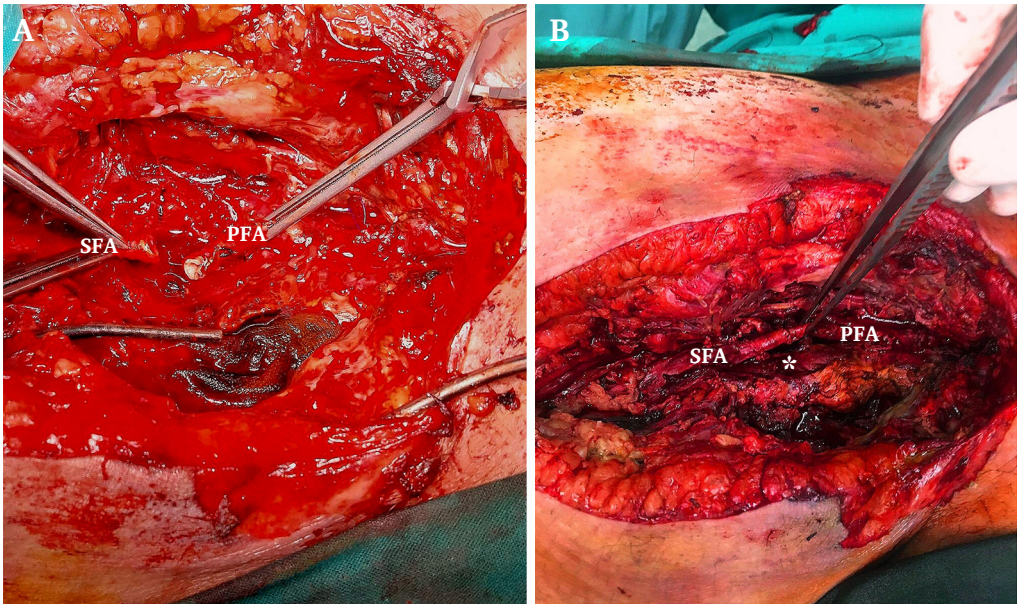

A 33 year old male intravenous drug user was referred urgently with right groin haemorrhage and acute limb threatening ischaemia after superficial femoral artery (SFA) puncture. A ruptured SFA pseudoaneurysm was detected by colour duplex ultrasonography. Young age, synchronous presence of abscess (*Pseudomonas aeruginosa* isolates), extensive tissue damage, and lack of appropriate venous conduit favoured an end to end anastomosis (A and B, asterisk) of the profunda femoral artery (PFA) to the distal SFA stump. Meropenem was administered for 21 days and a vacuum assisted closure device helped with wound healing. Using this provocative technique, successful revascularisation and lower limb salvage were achieved.

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