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EDITORIAL

European Society for Vascular Surgery (ESVS) 2021 Clinical Practice Guidelines on the Management of Venous Thrombosis

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The European Society for Vascular Surgery (ESVS) has developed a series of clinical practice guidelines for the care of patients with vascular diseases[1]. Their aim is to provide an evidence-based standard that helps clinicians in selecting the best management strategies to achieve optimal patient outcomes. Until now, the American College of Chest Physicians (ACCP) clinical guidelines for venous thromboembolism (VTE) management[2], the International Union of Angiology (IUA),[3] and more recently the American Society of Hematology (ASH) guidelines[4,5], have been used for such patients. These are the first ESVS guidelines on venous thrombosis (VT). The ESVS VT guidelines address acute deep vein thrombosis (DVT) of the lower extremity, upper extremity DVT (UEDVT), superficial vein thrombosis (SVT), thrombosis in unusual sites and catheter related thrombosis (CRT).

A literature search to 31 March 2018 was performed, as well as reference checking and hand searches by individual members of the Guideline Writing Committee (GWC). Aggregated evidence studies including meta-analyses, randomized controlled trials (RCTs), and observational studies were analyzed. The strength of recommendations were based on the quality of the studies relating to the specific recommendation. The level of available evidence for each section was used to guide the class of each recommendation in the guideline. The ESVS 2021 includes 72 recommendations, 33 of them are Class I, 21 are Class IIa, 7 are Class IIb recommendations, and 11 are Class III recommendations. The strength of evidence on which these recommendations were based was relatively weak, similar to the ACCP and ASH guidelines, with the vast majority of the recommendations being based on levels of evidence B and C which are considered to be moderate levels of evidence. The GWC also included some flowcharts of recommendations for the diagnosis and investigation of DVT, treatment for provoked and unprovoked DVT, and treatment for superficial vein thrombosis, promoting greater understanding of the sequence of steps for ideal management of the vascular disease.

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As expected ESVS VT 2021 guidelines have provided some novel recommendations compared with older guidelines. First, they highlight the significant need for including specific types of venous thrombosis and patient populations, as children, pregnant women, and cancer associated thrombosis (CAT). Secondly, the duration of principal - primary anticoagulation treatment for DVT is recommended for 3 months, contrary to ASH guidelines which proposed the period of 3 to 6 months as primary treatment. In this field, for patients with a provoked proximal DVT and a major transient risk factor, ESVS guidelines recommend anticoagulation therapy for three months over a shorter duration as a Class I recommendation, while ASH guidelines recommend a more extended period of three to six months. In contrary, the updated ACCP guidelines suggest against extending treatment more than 3 months for patients with VTE and major transient risk, while they have included recommendations for an extended phase therapy only in the absence of transient risk.

Moreover, according to ESVS 2021 VT guidelines initial and principal treatment of unprovoked proximal DVT is generally the same as with provoked DVT, with a direct oral anticoagulant (DOAC) being recommended over a vitamin K antagonist (VKA), as strong Class I recommendation and level of evidence A. Also in the same context, the recently updated ACCP guidelines suggested dabigatran, rivaroxaban, apixaban, or edoxaban over VKA therapy as anticoagulant therapy for a 3-month treatment phase with a strong recommendation, while ASH 2020 also agreed but with only moderate certainty[2,3]. A thorough discussion of the optimal anticoagulant therapy in cases needed extended therapy is also included in ESVS guidelines.

The authors of ESVS guidelines attempted to include the concept of patient status re-assessment when anticoagulation therapy is suggested. For patients with provoked proximal DVT and a persistent risk factor other than malignancy, ESVS guidelines are comparable to ACCP and ASH suggesting that anticoagulation beyond three months should be considered after evaluation of thrombotic and bleeding risks. Similarly, for patients with unprovoked DVT, continuing anticoagulation be-

yond three months is strongly recommended as Class I in ESVS guidelines, while both updated ACCP and ASH guidelines also include the recommendation of extended treatment in such cases. All guidelines have suggested reassessment of bleeding risk in such patients before deciding to proceed with, or continue, the extended-phase anticoagulation therapy.

For patients with unprovoked proximal DVT requiring extended anticoagulation beyond three months, a recommendation (Class IIa) with Level of Evidence B is included in ESVS guidelines for treatment with DOAC over VKA, as it is similarly suggested by updated ACCP. Although the same suggestion is supported by ASH guidelines, it is referred to as a Grade 2C, a weaker grade of recommendation. The ESVS guidelines diverge from ASH in respect to the patients with unprovoked proximal DVT requiring extended anticoagulation beyond six months, suggesting that a reduced dose of the DOAC apixaban (2.5mg twice daily) or rivaroxaban (10mg once daily) should be considered, as Class IIa, level B recommendation when ASH guideline panel less strictly suggests using either a standard-dose DOAC or a lower-dose DOAC. Recently, the updated ACCP also included the same suggestion as ESVS with a weaker level of recommendation.

In the field of Catheter-Directed Thrombolysis (CDT) for Acute DVT of the Leg, ESVS guidelines made an impactful change compared to ACCP and ASH which both suggest anticoagulant therapy alone over CDT. ESVS guidelines suggest that early thrombus removal strategies should be considered (Class IIa), especially in patients who are at highest risk of developing post-thrombotic syndrome (PTS), such as those with symptomatic iliofemoral deep vein thrombosis. The early thrombus removal reduces moderate to severe PTS, as referred by the authors, but also increases major bleeding.

An important suggestion in respect to the use of elastic stockings for acute DVT of the leg has been included in the ESVS guidelines. For patients with proximal DVT, early compression at 30 - 40 mmHg with either multilayer bandaging or compression hosiery, applied within 24 hours, is recommended to reduce pain, oedema, and residual venous obstruction, with a strong recommendation (Class I, level A). Moreover, in proximal DVT, use of below knee compression stockings should be considered to reduce the risk of post-thrombotic syndrome, as Class IIa. In proximal DVT with limited symptoms and signs, as described in the Villalta score, it is recommended as Class I, to limit the use of below knee stockings to six or 12 months. This guidance supporting the use of elastic stockings from ESVS contrast with both ACCP and ASH guidelines which suggest against using compression stockings routinely to prevent PTS (Grade 2B). Prevention of PTS has been discussed in ESVS guidelines although the clinical effectiveness of ECS in PTS prevention has yet to be identified.

Recommendations for patients with calf vein DVT have been included in ESVS guidelines as specified patient population although there is a lack of RCTs specific for different clinical scenarios. With this in mind, the authors suggested use of anticoagulation based on low level evidence (level C) as anticoagulation has been proved to be superior to no anticoagulation. Precisely, in patients with calf DVT, a decision for anticoagulation based on symptoms, risk factors for progression and bleeding risk should be considered as Class IIa, level C recommendation. What is more, for those with symptomatic calf DVT requiring anticoagulant treatment, three months of therapy is strongly recommended over shorter durations, as Class I, level A recommendation.

For patients with cancer-associated DVT, a low-molecular weight heparin (LMWH) is recommended for initial and principal phase anticoagulation (Class I, level A) as they are more effective than VKA. This contrasts the updated ACCP, which suggest the use of oral Xa inhibitor (apixaban, edoxaban, rivaroxaban) over LMWH for the initiation and treatment phases of therapy, as a strong recommendation. However, it is noticed by the authors that both apixaban and LMWH may be the preferred option in patients with luminal GI malignancies who place higher value on avoiding GI major bleeding, since edoxaban and rivaroxaban appear to be associated with a higher risk of gastrointestinal major bleeding compared to LMWH. Recently ASH guidelines specific for cancer patients are also in contrast with ESVS suggesting either apixaban, rivaroxaban or LMWH for initial treatment of VTE as a conditional recommendation with very low certainty of evidence. ESVS guidelines have suggested that for patients with malignancy not located in the gastrointestinal or genitourinary systems, an approved DOAC for initial, principal and extended treatment should be considered as Class IIa, level of evidence A, based on studies reporting effectiveness of DOAC over the LMWH dalteparin in preventing VTE recurrence. However, it is noticed that a non-significant trend for a higher risk for major bleeding accompany DOAC rather than the LMWH dalteparin.

ESVS has included some key points regarding to use of the Inferior Vena Cava (IVC) filters. While ACCP recommends against the use of an IVC filter in addition to anticoagulants (Grade 1B) and ASH suggests anticoagulation alone rather than anticoagulation plus insertion of an IVC filter (Grade 2B), the ESVS VT guidelines report that during the initial or principal treatment phase, temporary IVC filter insertion is recommended, as Class IC recommendation, for patients with proximal DVT who have contraindications to anticoagulation. In the same context, the updated ACCP has also included the same suggestion with strong recommendation grade, while the updated ASH for cancer patients included the use of an IVC filter as a remark suggesting that it may be required in such cases as well. For patients who are anticoagulated for DVT, all three guidelines' panels agree against the routine use of IVC filters.

In conclusion, some key points and initiatives in comparison to other guideline panels have been identified to help clinicians improve their practice, underlying the need for high-quality comparative effectiveness research in the venous thrombosis field in order to improve healthcare. Meticulous evaluation of the published literature made it possible for the ESVS VT authors to develop well justified recommendations for optimal clinical practice and ultimately improvement of the outcomes of patients with venous thrombosis. Although some uncertainty remains regarding management of special patient populations, ESVS VT 2021 have provided lucid guidelines for

Venous Thrombosis based on the latest data for management of vascular disease.

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Deep vein thrombosis as the first paraneoplastic presentation of undiagnosed cancer

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Abstract:

Introduction: Epidemiological studies reported a mean 4-12% prevalence of unrecognized cancer in patients with unprovoked deep vein thrombosis (DVT). The objective of our study was to assess the relation between unprovoked DVT and first diagnosis of a previously undiagnosed cancer and to investigate if it is justified to routinely screen these patients for malignancy with computed tomography (CT) scan.

Methods: We performed a retrospective analysis of medical records data of 276 patients with unprovoked extremity DVT admitted from 2015 to 2021. All patients underwent basic laboratory exams and a contrast enhanced CT scan of thorax, abdomen and pelvis with the purpose of screening for an occult, underlying tumor.

Results: In 46 patients (16.7%) a tumor was detected with malignancy confirmed in 37 cases (13.4%). In the majority (64.8%) the diagnosed tumor was confined to the primary organ with no or limited lymph node metastasis. In 16.2% the tumor was at advanced, metastatic stage. Lung (24.3%) and kidney (21.6%) were the most frequent primary locations, followed by colorectal (16.2%) and pancreatic (13.5%) cancer.

Conclusion: Patients presenting with unprovoked DVT have a relatively high possibility of an underlying malignancy, indicating that high level of medical awareness is advised. Routine screening of these patients with CT scan may be helpful for the early diagnosis of cancer.

Key words: deep vein thrombosis, cancer, paraneoplastic syndrome, computed tomography, diagnosis

INTRODUCTION

The relationship between venous thromboembolism (VTE) and cancer was first hypothesized by Virchow and reported by Trousseau in 1865.[1] An important amount of recent epidemiological studies has suggested the increased prevalence of VTE in terms of deep vein thrombosis (DVT) with or without pulmonary embolism (PE) in patients with cancer.[2-5] The mechanisms leading to this are associated with the Virchow's triad of blood stasis, endothelial injury and hypercoagulability, especially since cancer is considered as an hypercoagulable state.[1-2] Patients with known malignancy are reported to have a 5-fold increased rate of developing VTE, with an annual incidence of 0.5% compared with 0.1% in the general population.[5-6] Approximately, 4-20% of these patients will develop VTE at some stage of their disease.[5-6]

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What is interesting is the fact that cancer patients tend to develop DVT more often in the initial period following the diagnosis of cancer.[7] Moreover, an amount of patients with unprovoked DVT and without a history of malignancy are diagnosed with cancer during the VTE treatment, usually during the first months after the VTE diagnosis.[7] This lead to the question whether the development of DVT could be useful as an early diagnostic marker of undiagnosed, occult cancer in the general population, thus leading to earlier diagnosis and better treatment options for these patients.[7-8] Epidemiological studies reported a 4-12% prevalence of unrecognized cancer in patients with unprovoked DVT, which is lowered to 2-6% in patients with other known VTE risk factors.[9-14] However, the prevalence of DVT seems to vary greatly between individual studies depending on the sample size, patients' individual characteristics, the inclusion and exclusion criteria and the diagnostic imaging method used for detecting an occult and possibly malignant tumor.[9-14]

Aim of this study is to quantify the correlation between unprovoked DVT and first diagnosis of a previously unknown cancer, to determine the possible confounding variables and to investigate whether it is justified to routinely screen these patients for malignancy.

METHODS

We performed a retrospective analysis of prospectively col-

lected data from DVT patients from a single vascular surgery university tertiary center. The study period covered seven years from 2015 to 2021 and the investigational protocol was approved from our institutional ethics committee. A total of 359 consecutive patients with DVT of the lower or upper extremity were admitted in our department. From analysis were excluded all patients with history of thrombophilia, autoimmune diseases and/or cancer the last 10 years and/or with any other risk factor which could have provoked the thrombosis. Patients lost during follow up were also excluded. Eighty-three patients met these criteria and were excluded and finally 276 patients were enrolled in analysis.

Prior to admission, all patients were examined at the emergency department and were assessed with the Wells DVT score for the probability of DVT. A detailed medical history was obtained with emphasis on the risk factors for VTE, comorbidities and previous history of VTE and/or cancer. Laboratory work-up included a complete blood count and a basic metabolic panel, as well as the basic coagulation tests (PT-INR, aPTT, fibrinogen levels) and D-dimers plasma levels. The diagnosis was made by means of real time B-mode compression venous ultrasonography and patients were admitted to our clinic. A chest X-ray and an electrocardiogram were performed upon admission. On day 1, we performed a detailed colored duplex venous ultrasound (cDUS) of the affected limbs. According to our protocol, an iodine contrast enhanced CT scan of the thorax, abdomen and pelvis after per os administration of gastrografin was performed on day 2, with the intention of discovering an occult PE and/or a subclinical and undiagnosed tumor. Graduated compression stockings were applied and an adjusted therapeutic dosage of low molecular weight heparin (LMWH) was administered daily for the duration of their stay. Post-discharge anticoagulant medication in patients with negative imaging workup included a direct oral anticoagulant (DOAC) in therapeutic dosage, such as rivaroxaban 20mg q.d. or apixaban 5mg b.i.d.. Patients with positive findings in imaging or laboratory work-up indicating a possible malignancy remained in LMWH treatment and were referred for oncological consultation to establish the definite diagnosis and for further treatment. All patients were followed-up both clinically and with cDUS at 3 months, 6 months and 1 year.

Statistical analysis

We reviewed the files of these 276 unprovoked DVT patients and recorded the patients' demographics (age, gender), individual patient risk factors such as smoking, comorbidities and medication with emphasis on antiplatelet or anticoagulant treatment. In cancer patients, the site of cancer, pathology report and TNM staging were reviewed. The data were entered in a computerized database and the statistical analysis was performed by using the IBM SPSS Statistics program - version 22.0 for macOS (IBM, NY, USA). Categorical variables are presented as counts and percentages and were analyzed with the chi-square test. Continuous variables that follow the normal distribution are presented as mean ± standard deviation (STD) and were analyzed with Student t-test, whereas those which do not follow the normal distribution are presented as median and interquartile range (IQR) and were analyzed with Mann-Whitney U-test. The significance level of the various performed statistical tests was defined at p-value < 0.050.

RESULTS

Forty-six patients (16.7%) with unprovoked DVT were found to have a previously undiagnosed solid tumor and further oncological specialist evaluation confirmed malignancy in 13.4% (n=37) of our series. Accordingly, the patients were divided in subgroup A, which included 239 (86.7%) patients free from malignancy, while patients with a malignant neoplasm (n=37, 13.4%) constituted the subgroup B. Table 1 shows the demographics, basic characteristics and clinical presentation data of the study sample, as well as of the two subgroups. Notably, male gender and smoking were significantly more frequent in subgroup B (p=0.030 and p=0.005, respectively).

In the vast majority of patients (n=266, 96.3%), the thrombosis was located at the deep veins of the lower extremities, with no difference between the two subgroups (p=0.256). Iliofemoral DVT was significantly more frequent in subgroup B (75.7% vs. 69.0%, p=0.018). Twenty-five patients (9.1%) experienced DVT under antiplatelet treatment, while six patients (6.2%) under anticoagulant treatment. No difference was discovered between the two subgroups (p=0.069 and p=0.099, respectively). PE was diagnosed in 30 cases overall (10.9%). All PE cases were subclinical, and a malignant tumor co-existed in 5 patients (13.5%) of subgroup B. Analysis showed that PE was found to be marginally correlated with neoplastic disease (13.5% vs. 10.4%, p=0.051).

Table 2 summarizes the blood analysis data of the commonly used factors in the evaluation of patients' coagulation and thrombotic potential. No difference was found between the subgroups regarding the platelet number (p=0.197). Mean fibrinogen levels were significantly higher in subgroup B (457 ± 70 vs 387 ± 64 mg/dl, p=0.037). Similarly, analysis showed that median D-dimers was more than two times greater in subgroup B compared with the relevant value in subgroup A (13.21 - 7.8 vs 6.13 - 6.4, p=0.003).

Table 3 depicts the primary location of the malignant tumors that were discovered through the CT scan in these 37 patients of our study sample. The most common primary sites for the neoplasms were the lungs (n=9, 24.3%) and kidneys (n=8, 21.6%), followed by the gastrointestinal tract (n=7, 18.9%) and pancreas (n=5, 13.5%). Notably, at 1-year follow-up none of the subgroup A patients were diagnosed with a neoplasm. Table 4 shows the TNM staging of these 37 malignant neoplasms at the time of the imaging diagnosis. The majority was diagnosed at an early stage (stages I and II), with the tumor confined to the primary organ (n=15, 40.5%) or with limited lymph node metastasis (n=9, 24.3%). Six patients (16.2%) were found at an advanced stage (stage IV), with distant metastases. It must be emphasized that during the time of imaging diagnosis none of these patients with primary or metastatic neoplasm experienced any symptom indicating or implying a possible underlying malignancy. In all stage I and II cancer patients, surgical resection of the primary tumor was

Table 1. Demographics, basic characteristics and clinical data of the study population

Variables	Patients with unprovoked DVT - n (%)			P-value
	All patients 276 (100%)	Subgroup A 239 (86.6%)	Subgroup B 37 (13.4%)	
Age (years)	65.1 ± 7.2	63.5 ± 7.1	67.9 ± 7.6	.101
Male gender	137 (49.6)	111 (46.4)	26 (70.3)	**.030**
Smoking	180 (65.2)	146 (61.1)	34 (91.9)	.005
Obesity, BMI >30	57 (20.7)	49 (20.5)	8 (21.6)	.123
CAD	30 (10.9)	26 (10.9)	4 (10.8)	.275
COPD	20 (7.2)	17 (7.1)	3 (8.1)	.185
CKD	25 (9.1)	15 (9.2)	3 (8.1)	.176
Antiplatelet [a]	25 (9.1)	21 (8.9)	4 (10.8)	.069
Anticoagulant [b]	6 (2.2)	5 (2.1)	1 (2.7)	.099
Lower limb	266 (96.3)	231 (96.7)	35 (94.6)	.256
Iliofemoral DVT	193 (69.9)	165 (69.0)	28 (75.7)	.018
PE	30 (10.9)	25 (10.4)	5 (13.5)	.051

***Abbreviations**: BMI body mass index, CAD=coronary artery disease, CKD=chronic kidney disease, COPD=chronic obstructive pulmonary disease, DVT=deep vein thrombosis, PE=pulmonary embolism.*

[a] *Aspirin or clopidogrel*

[b] *Dabigatran, rivaroxaban, apixaban or acenocumarol.*

Categorical variables are presented as n (%). Continuous variables are presented as mean ± SD. Statistically significant difference at p<0.050 level appear bold typed.

Table 2. Laboratory data of the study sample

Variables	Patients with unprovoked DVT - n (%)			P-value
	All patients 276 (100%)	Subgroup A 239 (86.6%)	Subgroup B 37 (13.4%)	
PLT (*10^3/μl)	342 ± 91	332 ± 92	361 ± 100	.197
INR	1.02 ± 0.07	1.03 ± 0.08	1.01 ± 0.09	.234
aPTT (sec)	34.5 ± 2.8	35.6 ± 2.7	32.9 ± 3.3	.138
FBG (mg/dl)	418 ± 68	387 ± 64	457 ± 70	**.037**
D-dimers (mg/L)	6.99 - 8.6	6.13 - 6.4	13.21 - 7.8	.003

***Abbreviations**: aPTT=activated partial thromboplastin time, FBG=fibrinogen, INR=international normalized ratio, PLT=platelets count.*

D-dimers are presented as median - IQR. Other continuous variables are presented as mean ± std. Statistically significant difference at p<0.050 level appear bold typed.

Table 3. Primary location of malignant tumors

Location	Total number n=37 n (%)
Lung	9 (24.3)
Kidney	8 (21.6)
Colorectal	6 (16.2)
Pancreas	5 (13.5)
Uterus	3 (8.1)
Non-Hodgkin Lymphoma	3 (8.1)
Other [a]	3 (8.1)

[a] Other includes stomach, liver and prostate cancer of 1 case each.

Table 4. Stage of cancer at the time of the diagnosis

TNM staging [a]	Total number n=37 n (%)
Stage I	15 (40.5)
Stage II	9 (24.3)
Stage III	7 (18.9)
Stage IV	6 (16.2)

[a] TNM criteria of each individual organ

performed promptly, with adjuvant chemotherapy in 11 of them (29.7%). In stage III patients, neoadjuvant chemotherapy +/- radiation therapy was performed first, followed by locoregional resection of the neoplastic tissues. Finally, in the five stage IV patients, chemotherapy and palliative care was applied. At 1-year follow-up two deaths were reported, both from the stage IV subgroup. No other major morbidity was reported. Notably, at 1-year follow-up none of the subgroup A patients were diagnosed with a neoplasm.

DISCUSSION

The relationship between venous thromboembolism (VTE) and cancer is well established, with DVT to be considered a common complication among cancer patients.[1-4] Patients with neoplasm seem to be in a prothrombotic state due to the development of paraneoplastic syndrome.[4-5] Epidemiological studies confirmed the relatively high incidence of an unrecognized cancer in patients with unprovoked extremity DVT, but there seems to be no consensus in actual prevalence and the extent of screening. The reported incidence varies from 7.2% to 13.1%.[9-14] The reason behind this variability between the individual studies seems to be related with the sample size, the patients' inclusion and exclusion criteria and the modality and extent of diagnostic imaging used for detecting a possibly malignant tumor.

Goals of our study were to determine the prevalence of occult malignant neoplastic disease in patients with unprovoked DVT and to investigate the value of routine CT imaging in early detection of undiagnosed neoplasms. The proper imaging approach of DVT patients should implicate the presence of a silent PE as well of a malignant tumor.[14-15] Contrast enhanced thorax, abdomen and pelvis CT scan with per os gastrografin is a modality with great availability and feasibility in general practice, which combines the ability of high accuracy in detection of both PE and neoplasms and was therefore the selected method of routine imaging in our study.[15] Other imaging modalities such as magnetic resonance or positron emission tomography have equal or even greater diagnostic accuracy but the lack of availability and feasibility in general practice question their applicability as first line diagnostic tools for these patients.[15] The results of our study confirmed the high incidence of cancer (13.94%) in a total of 276 patients with unprovoked extremity DVT. Furthermore, during the 1st years' follow-up none of the 239 cancer-free patients was diagnosed with a new neoplasm.

Individual patient risk factors associated with an underlying cancer etiology are age, sex, race and comorbidities such as obesity, lung disease and renal failure.[9,12] A risk score for more extensive examination for cancer has been proposed, but it not validated.[13] In our study, only male gender and smoking were found to be significantly associated with diagnosis of cancer. Additionally, in 25 cases (9.1%) DVT was developed despite the fact that these patients were under antiplatelet treatment. In these cases, researchers have suggested an occult malignancy as the most likely underlying etiology, which triggers the thrombosis.[16] Our study confirmed a trend towards this direction but failed to prove this hypothesis (p=0.069). Regarding the clinical extent and severity, iliofemoral DVT was significantly more frequent in the cancer subgroup (75.7% vs. 69.0%, p=0.018). Moreover, the results showed that PE was marginally correlated with an underlying neoplastic disease.

Routine blood analysis results didn't seem to differ between the two subgroups. However, fibrinogen and especially D-dimers levels were found to be significantly elevated in patients with an occult malignancy, mirroring the hypercatabolic state of an active cancer. The median value of D-dimers was significantly higher in cancer patients of our series (13.21 - 7.8 vs 6.13 - 6.4, p=0.003) and this highlights the potential use of D-dimers as a marker of patients in risk of neoplastic disease. However, further research is required to achieve general agreement in this field.

Clinical manifestation of cancer in DVT patients is related with primary site, staging and histological type.[17-19] Malignant tumors of pancreas, uterus, lung, stomach, and kidney have been reported to be more frequent among DVT patients.[17-19] In our study kidney and lung cancer accounted for nearly half (45.9%) of our cases. Previous studies formulated the hypothesis that malignant tumors in DVT patients are usually contained to the primary organ site with limited to none lymph node metastasis and that this early detection is associated with better treatment options, better response to treatment and better overall survival rates. [17-20] Our study confirmed that 64.8% of the diagnosed malignant tumors were at stages I and II with no or limited lymph nodes infiltration and were set timely in the proper treatment. Widespread and incurable stage IV disease was found only in 16.2% of cases. Moreover, the only two deaths reported at 1-year follow-up came from the advanced stage IV, and not from the early stages. These results seem to ratify the rationale and need for routine CT cancer screening in patients presenting with unprovoked DVT.

However, the debate on the necessity and the extent of screening for malignancy when unprovoked DVT is diagnosed is ongoing and there is no consensus yet between researchers. A relatively high prevalence of an occult malignancy in patients with DVT does not automatically imply that extensive screening for cancer is indicated since it is unknown whether a substantial proportion of these malignancies can be diagnosed at a relatively early stage and whether earlier detection will ultimately lead to better treatment options and longer life expectancy.[21-23] Meta-analysis showed that extensive cancer screening diagnosed a higher number of malignancies compared with limited screening, but conferred no significant reduction in all-cause mortality or cancer related mortality.[10-11] Moreover, extensive screening is not without drawbacks. Physical and emotional distress, economical costs, false positive findings and hazards resulting from contrast and ionizing media must be taken into consideration.[10-11] The only thing for sure is that physicians dealing with unprovoked DVT should be aware of the possibility of an occult malignancy, especially during the first year of diagnosis.

Our study has the limitation of its retrospective, observational character, thus our results reflect only a particular time frame. A prospective, cohort study with a larger sample size and duration of follow-up is needed to assess the dynamics of cancer development in patients with unprovoked DVT and to provide useful results about the better diagnostic and treatment strategies. Moreover, a cost-effectiveness analysis should be performed evaluating the clinical and economical importance of routine CT-scan screening of all patients with unprovoked DVT in order to detect a possible underlying malignancy.

CONCLUSION

Patients presenting with unprovoked extremity DVT have a relatively high possibility of having an underlying, previously unknown malignancy. Routine screening with CT scan at the time of the DVT diagnosis in a general practice environment may be helpful as an diagnostic marker for the early diagnosis of malignancy. Therefore advanced awareness is advised. Further research is needed to determine whether CT screening should be performed as part of routine in all patients with unprovoked DVT.

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Contributorship: ZT and MT researched the literature. GP and DCC conceived and designed the study protocol. DAC and AP were occupied with protocol development, gaining ethical approval, patient recruitment and data collection and analysis. TK was involved in data collection and statistical analysis. DAC wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

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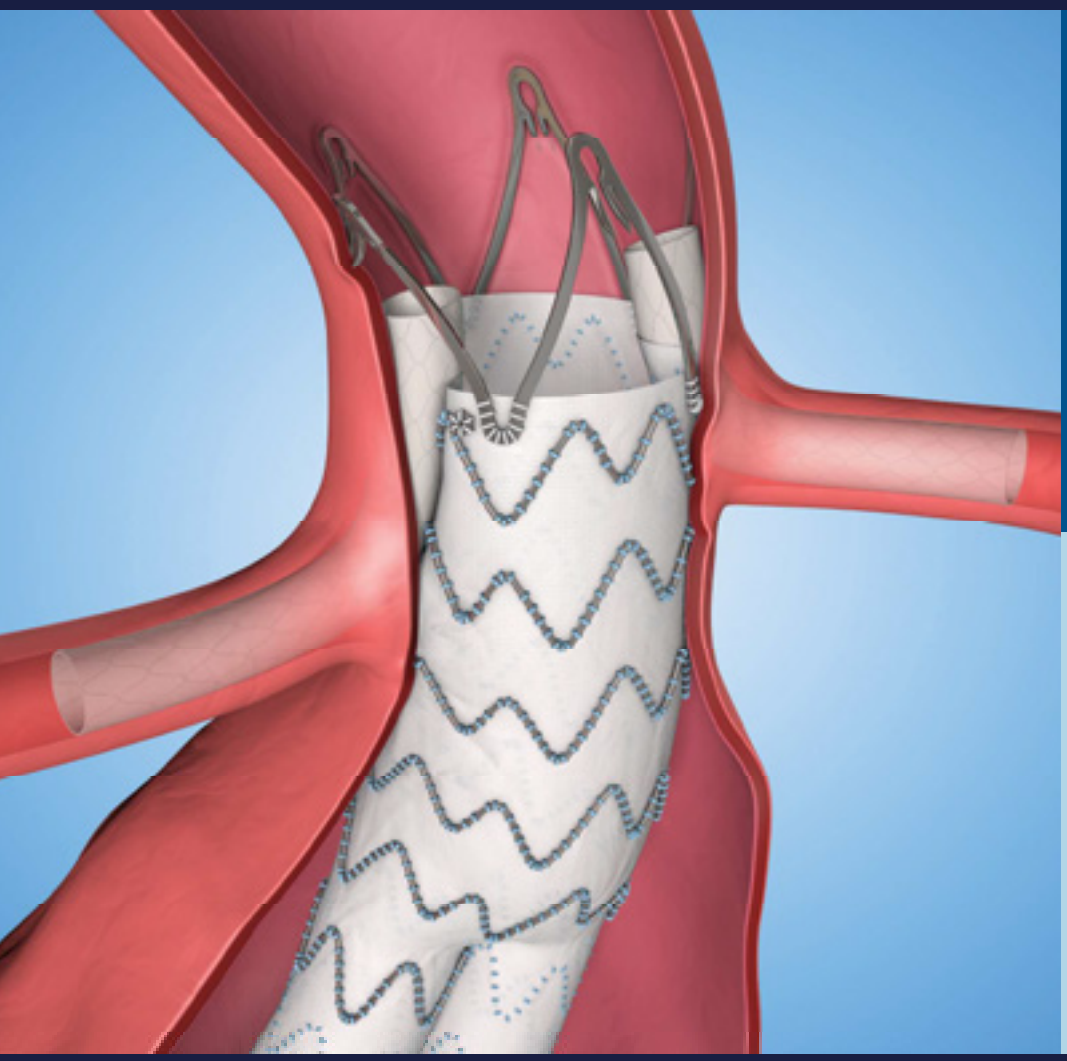

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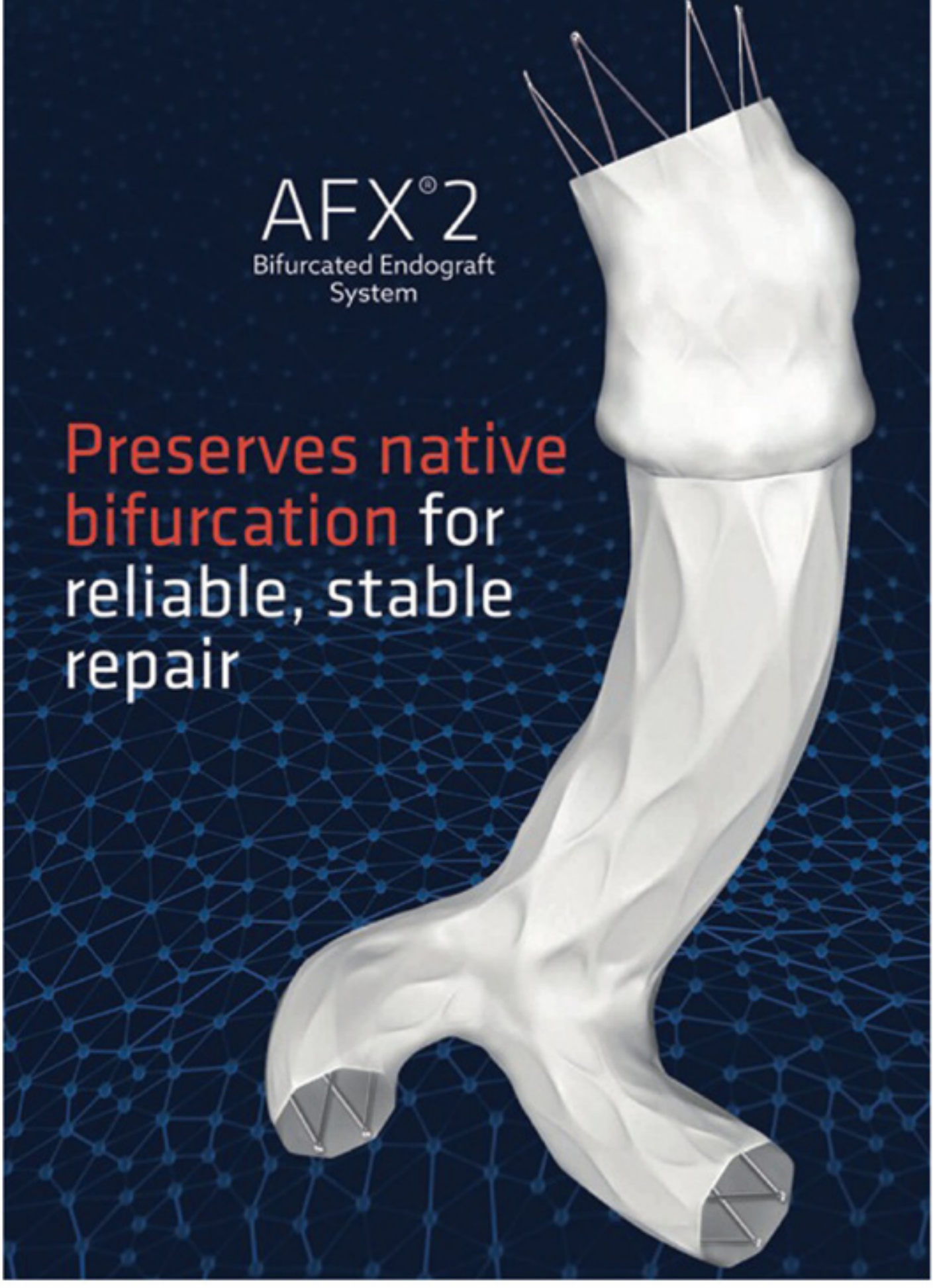

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Cabrol Graft Technique in Aortic Root Replacement: A Historical and Current Review

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Abstract:

In 1968, Bentall and De Bono reported a method for complete aortic root replacement involving side-to-side anastomoses of the right and left coronary arteries onto the aortic graft. This came to be known as the classic Bentall technique. In subsequent years, recognition of bleeding and pseudoaneurysm formation at the site of the side-to-side coronary anastomoses, among others complications, came to the fore. To address these issues, Kouchoukos developed his modification in which the coronary ostea, with a rim of aortic tissue, were detached completely from the aortic wall and anastomosed end-to-side onto openings in the main aortic graft. Cabrol et al in 1981 described an alternative technique in which a "moustache-shaped" interposition Dacron graft was used in a sub-group of patients whose ostea could not easily be brought into place. The ends of the moustache graft were anastomosed to the coronary buttons; then, the side of the moustache graft was anastomosed side-to-side to the main aortic graft. Several modifications of this surgical approach have been reported, as well as the complications developing in those who underwent the classic or modified Cabrol technique. We review this experience-positive and negative-here. Nowadays, the surgical treatment of aortic root aneurysm includes either a composite valve graft conduit (mechanical or biological valve), a stentless aortic root xenograft, or the popular valve sparing aortic root replacement. As all of these options require reimplantation of the coronary ostia onto the primary graft, several coronary reimplantation surgical techniques have evolved. This literature review aims to characterize the history, modifications, and reported outcomes of the classic Cabrol technique and its modifications.

Keywords: Aortic root replacement, coronary reconstruction. graft interposition, Cabrol graft, coronary button

INTRODUCTION

Reimplantation of the coronary artery ostea (right and left) onto the aortic graft is a requirement and a key stage during an aortic root aneurysm surgery. Among different techniques that have been developed, the first was reported in 1968 by Bentall and de Bono[1], who in a side-to-side fashion anastomosed the aneurysm wall carrying the coronary ostia onto the aortic conduit (Figure 1). In subsequent years, complications were noted in patients who had undergone the classic Bentall approach. Those complications included excess or uncontrollable bleeding at the time of surgery, as well as late pseudoaneurysm formation at the side-to-side anastomoses. To address those complications, Cabrol et al[2] reported in 1981 an alternative technique, applied in a sub-group of patients, in which a "moustache-shaped" interposition graft was anastomosed

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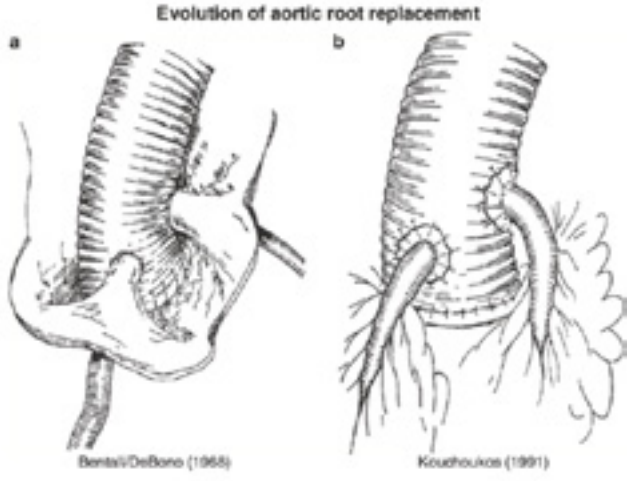

Figure 1. Techniques for direct coronary anastomosis onto the aortic graft. (**a**) Bentall/DeBono technique. Note how the coronary arteries remain part of the aortic carcass, which itself is brought up to the aortic wall and attached in side-to-side fashion. (**b**) Kouchoukos technique. Note that the coronary artery, with a surrounding "button" of aortic wall is detached completely from the aortic carcass and brought up for an end-to-end anastomosis to the new Dacron graft. (Reprinted with permission from Platis et al. [Platis IE, Kopf GS, Dewar MS, Shaw RK, Elefteriades JA. Composite graft with coronary button reimplantation: procedure of choice for aortic root replacement. Int J Angiol. 1998;7:41-5]).

in an end-to-end fashion onto each coronary ostium and in a side-to-side fashion onto the aortic conduit (Figure 2). Several modifications of this surgical approach have been documented. Furthermore, complications in those who received either the classic or modified Cabrol technique have been described by multiple authors. Although the current gold standard for composite graft or valve-sparing aortic root replacement is the "button-technique" described by Kouchoukos et al [3] (Figure 1), these Cabrol modifications remain critically useful in anatomic situations where direct coronary button reimplantation is not feasible. This need arises in case of specific anatomic irregularities that prevent safe, direct button reimplantation. This is usually related to inability of coronary buttons chronically displaced far away from the centerline of the aorta by massive aortic root enlargement ("giant root aneurysms"); such buttons may not be able to "reach" the much smaller replacement graft. Other potential situations include reoperations, where scarring prevents safe coronary button mobilization. Also, in cases where rotational mal-positioning of the coronary buttons produces torsion, this can be alleviated by an interposition Cabrol graft. The aim of this literature review is to characterize the history, modifications, and reported outcomes of the classic Cabrol technique and its modifications.

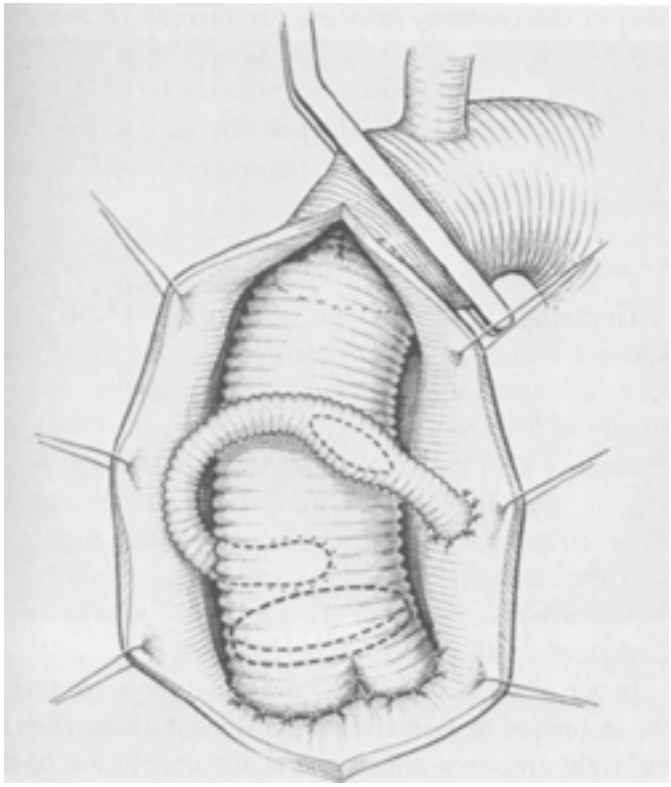

Figure 2. This Figure shows the aorta replaced by the "inclusion" technique. This is rarely used in the present era for ascending replacement; currently, resectional replacement is preferred. We use the original Cabrol diagram for its historical relevance. (Reprinted with permission from Cabrol et al.[2]). Note that the two ends of the small caliber Cabrol graft are anastomosed over the coronary ostea (right and left). This can be done onto the aortic wall or onto detached coronary artery buttons.

HISTORY

In 1956, prior to the development of coronary reimplantation surgical techniques, Cooley and De Bakey[4] reported the first successful supracoronary intervention for a fusiform aneurysm of the ascending aorta. With that report, the authors introduced the use of cardiopulmonary bypass in aortic aneurysm surgery. In 1964 Wheat et al[5] described successful replacement of the ascending aorta and aortic valve in a patient with an aneurysm extending proximal to coronary ostia. In this case, a tongue of aortic wall was left surrounding the two coronary ostia, allowing the sutures to be distant from the lumen of the ostia and thus reducing the risk of thrombosis and tension on the coronary arteries.

In 1968 Bentall and De Bono [1] described a ground-breaking surgical technique that took cardiac surgery by storm. Their one-page paper has become a classic in terms of clarity and efficient use of words and line drawings. In this bold, novel technique, the previously unapproachable coronary ostia were reincorporated into the side of the aortic graft through an end-to-side anastomosis (Figure 1). This came to be called the classic Bentall technique. Throughout 1970s, studies reported the difficulty in coronary reimplantation and suturing; the procedure was complicated by more than occasional intraoperative bleeding at the aortocoronary suture lines, or, later development of a pseudoaneurysm at the site of the coronary ostial anastomosis[6]. These difficulties were thought to arise from failure to incorporate the full thickness of the aortic wall (with the strong adventitia) into the coronary suture line.

Alternative techniques were developed to handle these problems. In 1975 Blanco et al[7] reported an end-to-end anastomosis of reversed saphenous vein segments between the coronary ostia and the main aortic graft. Zubiate et al[8] in 1976 described the use of saphenous vein grafts to "transpose the origin of coronary arteries" or to bypass more distally, to the standard coronary graft locations on the right and left coronary arteries. (Figure 3).

Neveux et al[9] reported an imaginative alternative technique for the setting of a low coronary ostium that would not allow direct and tension-free coronary reimplantation. In this surgical approach, by making a hole in the aortic graft that preserves the prosthetic wall as a lower flap of aortic prothesis, a trap door effect with a lower hinge was created (Figure 4). This allowed direct coronary reimplantation in cases of a low-lying coronary artery ostium. This technique essentially brings the aortic graft material "down to" the comfortable location of the coronary artery button.

In 1981 Cabrol and colleagues[2] reported their alternative technique in which each coronary ostium was anastomosed end-to-end to the ends of an 8 mm polyester tube graft, which itself was anastomosed side-to-side to the main aortic graft (Figure 2). In the subsequent years, several additional modifications of this Cabrol surgical technique were developed.

Also, as experience with full aortic root replacement grew, clinical patient outcomes were able to be assessed with the different techniques.

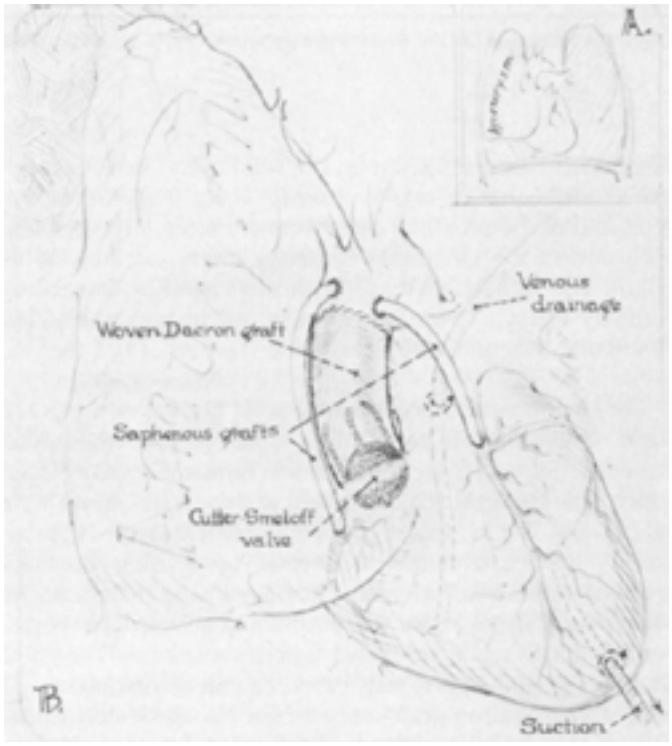

Figure 3. "Transposition of coronary arteries" origin using saphenous vein grafts (Reprinted with permission from Zubiate et al.[8]) This particular drawing, from the original authors, actually shows typical saphenous vein graft bypass to the coronary arteries themselves rather than to the coronary ostea.

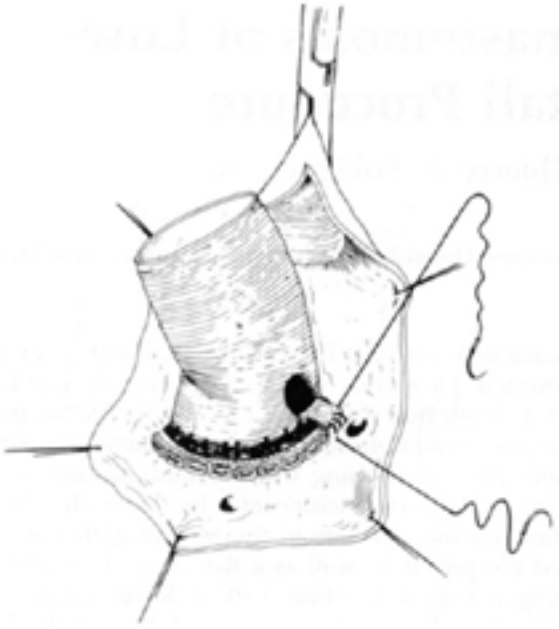

Figure 4. Direct reattachment of a low-lying coronary ostium (Reprinted with permission from Neveux et al.[9]) Note how maintaining some graft material as a lower flap brings the anastomotic construct lower, closer to the tight coronary artery.

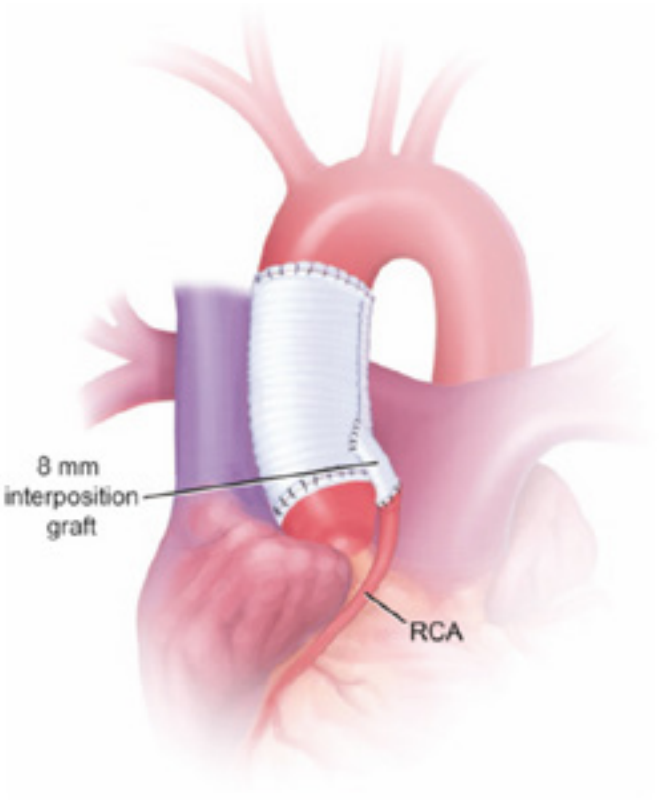

Figure 5. Coronary ostium reimplantation using a short interposition polytetrafluoroethylene graft (Reprinted with permission from Elefteriades et al. [Elefteriades JA, Ziganshin BA. Practical tips in aortic surgery: Clinical and technical insights. Springer. 2021: 151]) This is like a single-sided "Legs" technique developed by Mills[15].

MODIFICATIONS

Piehler and Pluth[10] described in 1981 the first modification of the classic Cabrol technique. This approach was used by the authors in 5 cases, all with limited mobility of the supraannular aorta for direct reimplantation of the coronary ostium onto the aortic conduit. Short interposition polytetrafluoroethylene grafts were used between the coronary ostium and the aortic graft (Figure 5). It has been debated whether this technique was a modification of the classic Bentall or of the Cabrol technique.[11] While Maureira et al[12] and Hirasawa et al[13] categorized this as a modified Bentall technique, Kourliouros et al[14], Mills et al[15] and Ziganshin et al[11] referred to it as a modification of the classic Cabrol technique. In this review, all coronary reimplantation techniques that require an interposition graft will be classified as modified Cabrol technique (Table 1).

Alternative Interposition Graft Options

In 1996 Mills et al[15] reported the use of a Cabrol modification technique called the "Legs" technique in ten patients. An 8-mm collagen-impregnated knitted Dacron graft was anastomosed on each coronary ostium, then transected, and finally anastomosed onto the aortic conduit (Figure 6). Advantages of the "Legs" technique-specifically reduced risk of kinking, thrombosis, graft compression, and atherosclerosis-compared to the classic Cabrol approach, were reported by the authors.

Table 1. Reports on modified Cabrol procedure

Source	Year	No. of patients with the procedure	Technique
Piehler et al[10]	1981	5	Interposition Gore-Tex graft
Mills et al[15]	1996	10	"Legs" technique
Kourliouros et al[16]	2011	1	-Gore-Tex anastomosis from valve conduit to right coronary ostium -T-graft anastomosis to the left mainstem
Cheng et al[17]	2018	6	-Main graft with one or more branches -Coronary ostium-side branch anastomosis -Use of interposition graft when direct anastomosis is not feasible

CABG, coronary artery bypass graft

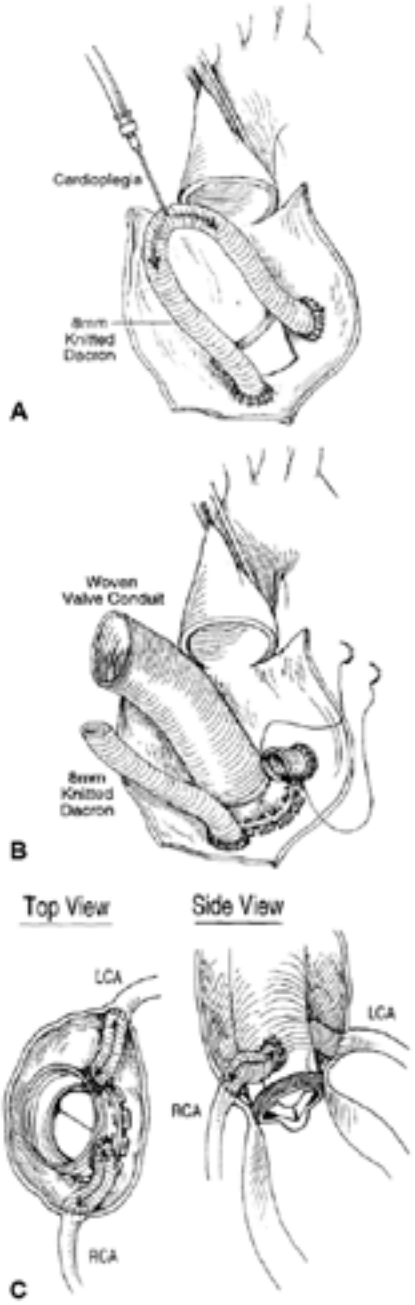

Figure 6. "Legs" technique. The interposition graft is (**A**) anastomosed on each coronary ostium, (**B**) transected, (**C**) anastomosed onto the aortic graft (Reprinted with permission from Mills et al.[15])

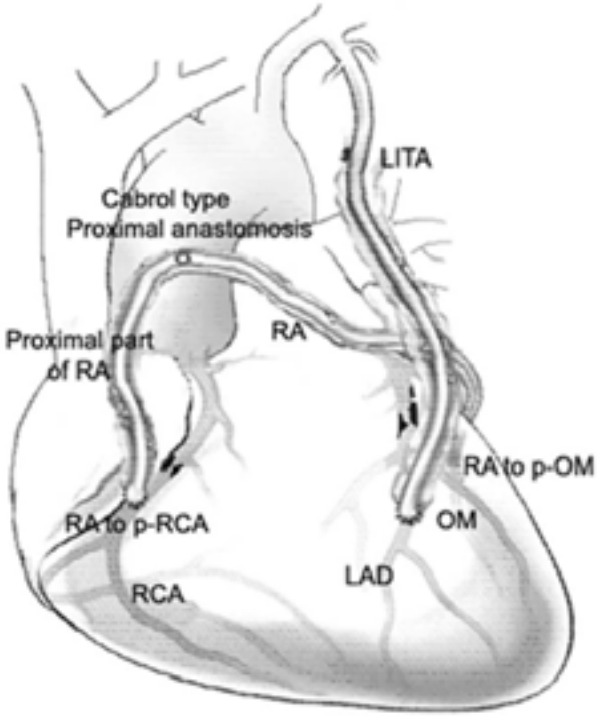

Figure 7. Coronary reimplantation using a radial artery graft in the setting of an off-pump CABG (Reprinted with permission from Jo et al[16]).

In additional work, in 2011 Kourliouros et al[16] documented the use of the modified Cabrol technique in a patient with bicuspid valve aortopathy. An 8-mm polytetrafluoroethylene conduit was used, which was anastomosed onto a 23-mm valved conduit and the right coronary ostium. The graft of the left mainstem was anastomosed in a T-fashion end-to-side onto the right aortocoronary Gore-Tex conduit (Figure 8).

Recently, Cheng et al[17] reported a new coronary reimplantation alternative in a complex reoperative setting. This was performed in 6 patients, all of them reoperative cases, of whom 3 were done for acute Stanford type A aortic dissection. A main graft with one or more branches was used. When a direct anastomosis between the coronary ostium and the side branch was not feasible, a 6 to 8 mm interposition graft was anastomosed to the coronary ostium and the branch of the root graft (Figure 9).

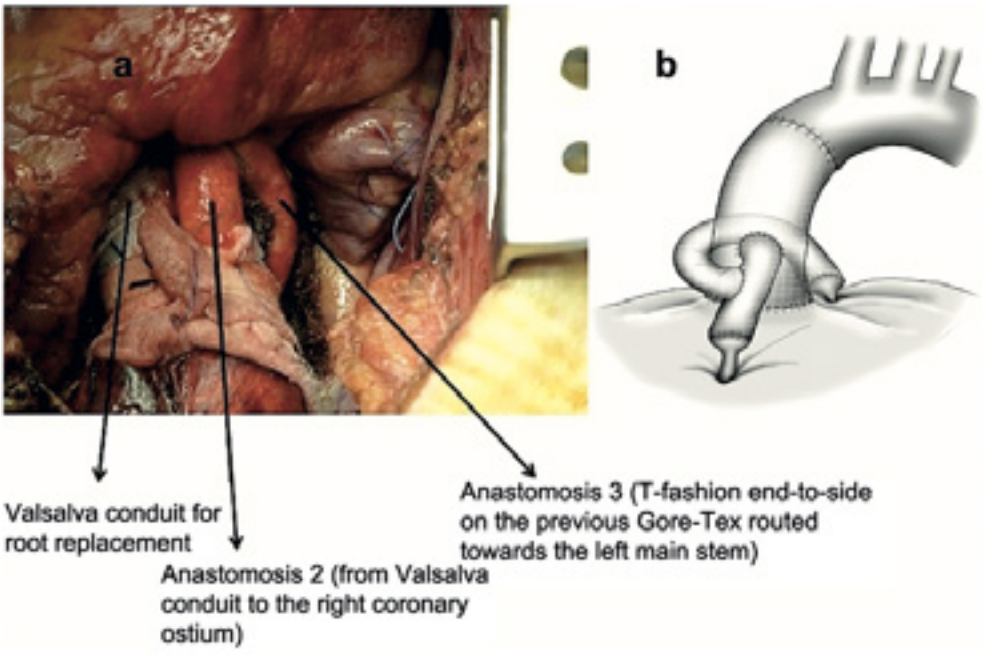

Figure 8. Using a Gore-Tex conduit for coronary reattachment (**a**) Intraoperative view (**b**) Schematic representation. (Reprinted with permission from Kourliouros et al.[17]) See text and labeling on photograph for details.

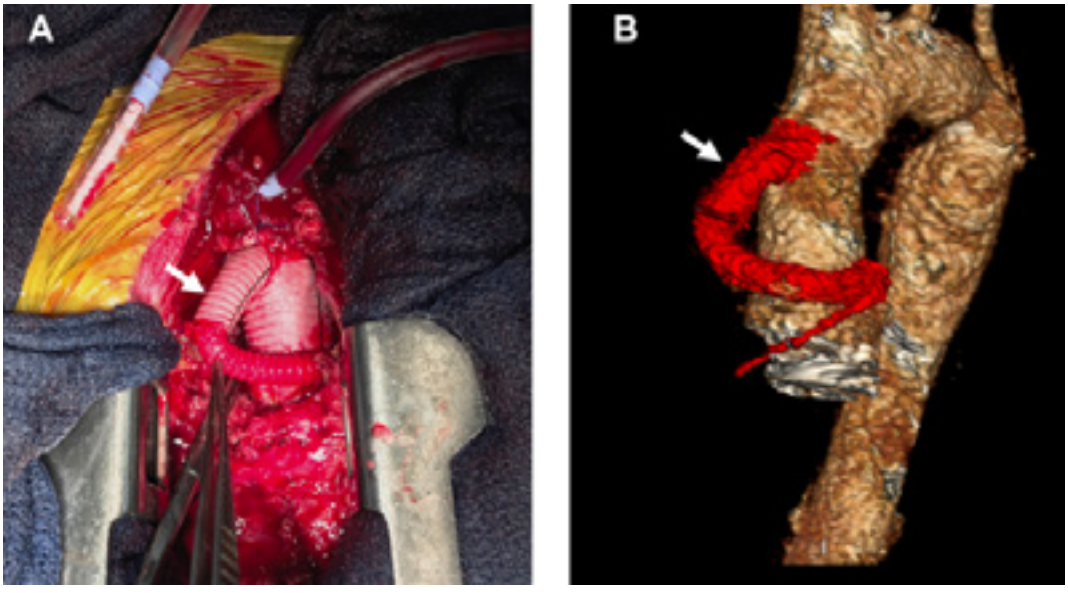

Figure 9. Use of a side branch graft for coronary reimplantation. (**A**) Intraoperative view (**B**) Radiology imaging. (Reprinted with permission from Cheng et al.[18]).

OUTCOMES

Multiple studies have documented the outcomes of patients who underwent either a classic or modified Cabrol technique (Table 2). Some of these studies included cases where coronary reimplantation was performed via the classic Bentall or the "button-technique" without using an interposition graft. In such studies, the outcomes related to the different techniques were grouped together. An early mortality between 0 to 41%, and a late mortality between 2.8 to 39% were reported in studies of cases performed with the original, classic Cabrol technique These widely varying (and at times very high) mortality rates reflect different eras of surgery and different acuities of presentation (including extremely acutely and critically ill patients). (Figure 10). On the other hand, the early mortality was between 2.8 to 10.4%, while the late mortality fluctuated between 1.4 to 16.8%, in studies of cases performed with a modified Cabrol procedure.

Among all the patients who underwent a Cabrol procedure in the studies included in Table 2, eight patients (0.8%) developed complications related to the Cabrol graft. These complications included graft thrombosis or occlusion and anastomotic pseudoaneurysm

Table 2. Reports on the outcomes of coronary reimplantation using an interposition graft

Source	Year	N (% Cabrol procedure)	Cabrol Technique		Early Mortality		Late Mortality		Survival Rate, %	Graft Complications, %
			Classic	Modified	N	%	N	%		
Cabrol et al[18]	1986	100	X		4	4	11	12	75 at 8 yrs	0
Svensson et al[19]	1992	348 (45)	X		13	8	__	__	76 at 3 yrs	1,3 RCA occlusion
Lund et al[20]	1993	17	X		7	41	0	0	100 at 3 yrs	5.9 Right limb graft occlusion
Jault et al[21]	1993	339 (77)	X		26[a]	7.6[a]	70[a]	22.4[a]	60 at 9 yrs[a]	0
Aoyagi et al[22]	1994	66 (20)	X		7[a]	10.6[a]	12[a]	20.3[a]	59 at 15 yrs[a]	0
Midulla et al[23]	1994	140 (30)	X		6	20	14[a]	10.5[a]	52 at 5 yrs	0
Bachet et al[24]	1996	203 (13)	X		15[a]	7.3[a]	30[a]	18.4[a]	58 at 8 yrs	3.8 Graft thrombosis
Gelsomino et al[25]	2003	45	X		9	20	6	16.6	59 at 16 yrs	2.2 LCA graft limb occlusion
Hirasawa et al[13]	2006	71		X	3	4.2	1	1.4	94 at 5 yrs	0
Garlicki et al[26]	2006	25	X (24%)	X (76%)	0	0	2	8	__	0
Jault et al[27]	2006	77 (45)	X		8[a]	10.4[a]	27	39[a]	42 at 12 yrs[a]	__
Kitamura et al[28]	2011	36	X		1	2.8	7	20	73 at 10 yrs	5.5 RCA ostium occlusion (2.77) RCA ostium stenosis (2.77)
Maureira et al[12]	2012	153		X	13	8.5	23	16.8	74 at 10 yrs	0.6 Anastomosis pseudoaneurysm
Ziganshin et al[11]	2013	40		X	3	7.5	6	16.2	73 at 6 yrs	0
Mok et al[29]	2017	449 (10)		X	14[a]	3.1[a]	52[a]	12[a]	82 at 10 yrs[a]	0

[a], results for the overall sample; RCA, right coronary artery; LCA, left main coronary artery.

Recently, the Yale Aortic Institute reported outcomes following composite graft aortic root replacement in 449 patients operated by a single surgeon over a 25-year period[30]. All patients underwent a modified Bentall-de Bono procedure with coronary button reimplantation and in 45 patients a modified cabrol procedure (Dacron coronary graft) was used. Operative mortality in the last 10 years was 2.2%. and freedom from reoperation on the aortic root was 97.9% at 20 years (Figure 11). In addition, patients aged less than 60 years had a long-term survival at 20 years of 79.8%, not substantially different from an age and gender matched normal population. This data reflects the low surgical risk, excellent long-term survival, and low incidence of reoperation following composite graft aortic root replacement.

Acute Myocardial Ischemia Management in the Operating Room

Coronary-related complications after aortic composite graft replacement are an uncommon but lethal condition. Ischemia related to coronary button reimplantation must be suspected in any case of severe arrythmia, difficulty in separating from the CPB, pump failure, and intra-operative echocardiographic evidence of regional wall motion abnormalities. Button related ischemia is a technical complication that may be caused by kinking or axial rotation of the coronary buttons after their extensive mobilization (Figure 12). At the same time, too little mobilization of the buttons can produce graft tension (too short), thus compromising coronary blood flow. Our recommendation is that during the anastomosis of the coronary buttons, they should only be mobilized enough to reach the aortic composite graft. With excess mobilization, the now "naked" unsupported proximal coronary vessel is bereft of its normal attachments to surrounding tissues and liable to kinking, torsional, or stretching misadventures. Furthermore, to preserve the anatomic position between the button and the aortic graft, it is recommended to mark each coronary button at the 12 o'clock position[31] (Figure 13). In cases where a direct coronary button anastomosis is not feasible or comfortable, a graft-based Cabrol anastomosis is extremely useful and often life-saving.

The Yale Aortic Institute has documented the utility of "Rescue CABG" surgery immediately after aortic root replacement in patients with suspected acute myocardial ischemia[31,32]. A 5-year survival rate of 100% was reported in those who underwent this surgical procedure[31]. Furthermore, it was identified that non-obstructive coronary calcification of the right or left main coronary artery predisposes to angulation of the coronary button after its anastomosis, with the calcium deposit serving as a fulcrum for angulation[32].

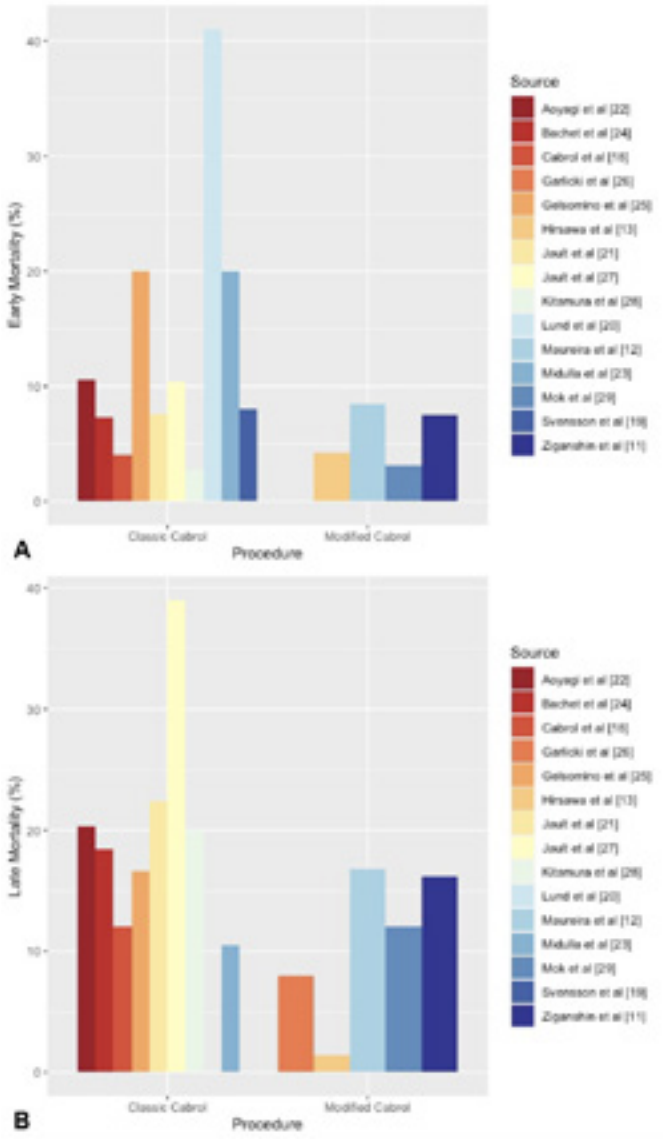

Figure 10. Clinical outcomes of using an interposition graft for coronary reimplantation. (**A**) Early mortality (**B**) Late mortality (**C**) Survival rate. C, classic Cabrol technique; M, modified Cabrol technique.

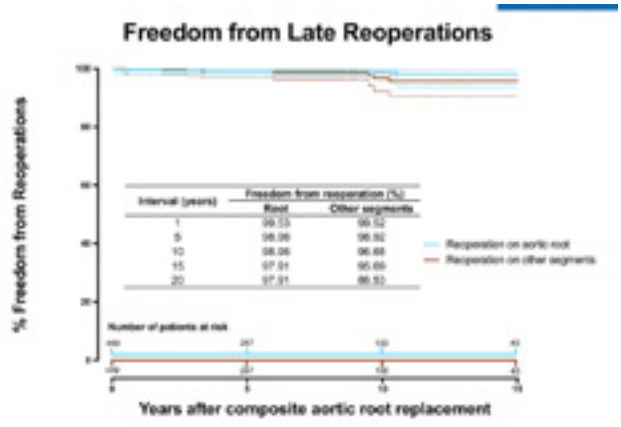

Figure 11. Freedom of reoperation on the aortic root and on other segments. At 10 years the freedom of reoperation on the aortic root was 99% (Reprinted with permission from Mok et al[30])

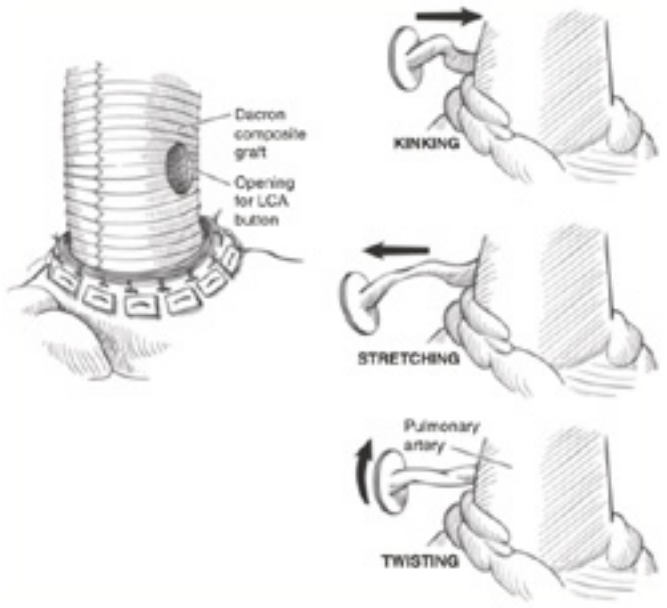

Figure 12. Kinking, stretching, and twisting of the coronary artery after coronary button attachment into the Dacron graft (Reprinted with permission from Shahriari et al[31])

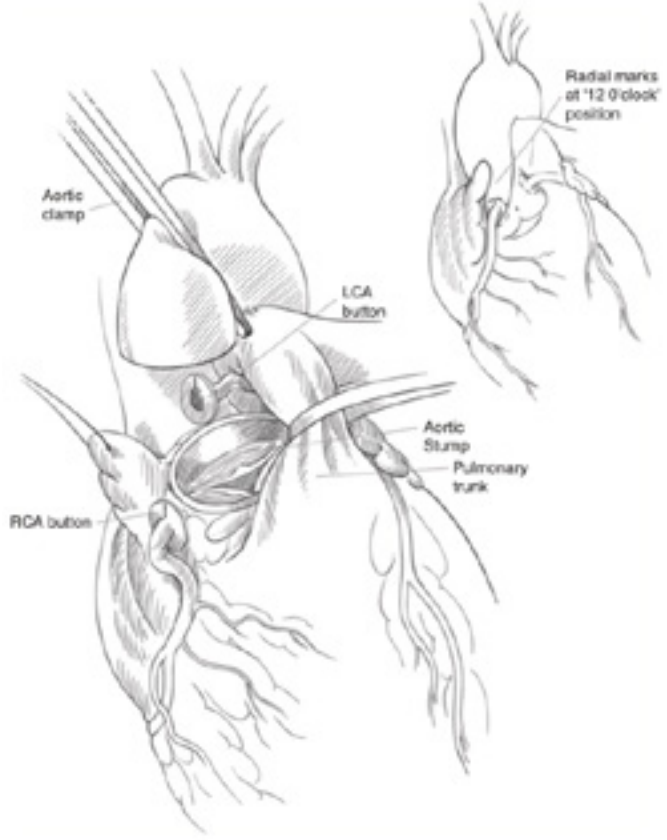

Figure 13. Mobilization of the coronary buttons at the 12 o'clock position (Reprinted with permission from Shahriari et al[31])

CONCLUSION

It has been four decades since the report of the classic Cabrol procedure. During this time, several substantive modifications to this technical procedure have been developed. Also, in the

last two decades, multiple studies have provided evidence on the durability and safety of various Cabrol modifications. These modifications, all graft based, are not recommended routinely, but for anatomic situations in which direct coronary button reattachment is not feasible.

Currently, the most widely used coronary reimplantation method is the "button-technique" described by Kouchoukos and Karp[3] (Figure 1). The exceptionally brief paper by Bentall and DeBono, first describing complete replacement of the aortic root, changed cardiac surgery forever-providing for the first time the ability surgically to replace the aortic root in its entirely, including the root, the ascending aorta, and the coronary ostia. Countless patients have benefitted since that time. The procedure pioneered by Bentall and DeBono and modified by Kouchoukos has proven durable in many long-term studies. This story serves as a vivid example of technical ingenuity leading to long-term saving of life. The Cabrol graft, the precise topic of this review, has served as an ingenious modification of the original composite graft procedure, which has been life-saving in its own right.

Note: Two aortic related procedures carry the "Cabrol" name. The coronary procedure, which is the topic of this paper, should be distinguished from the completely different "Cabrol shunt", which involves using a patch to divert perigraft bleeding into the right atrium.

Conflict of Interest Statement: Dr. Elefteriades: Principal of Coolspine. All other authors report no conflict of interest relative to this work.

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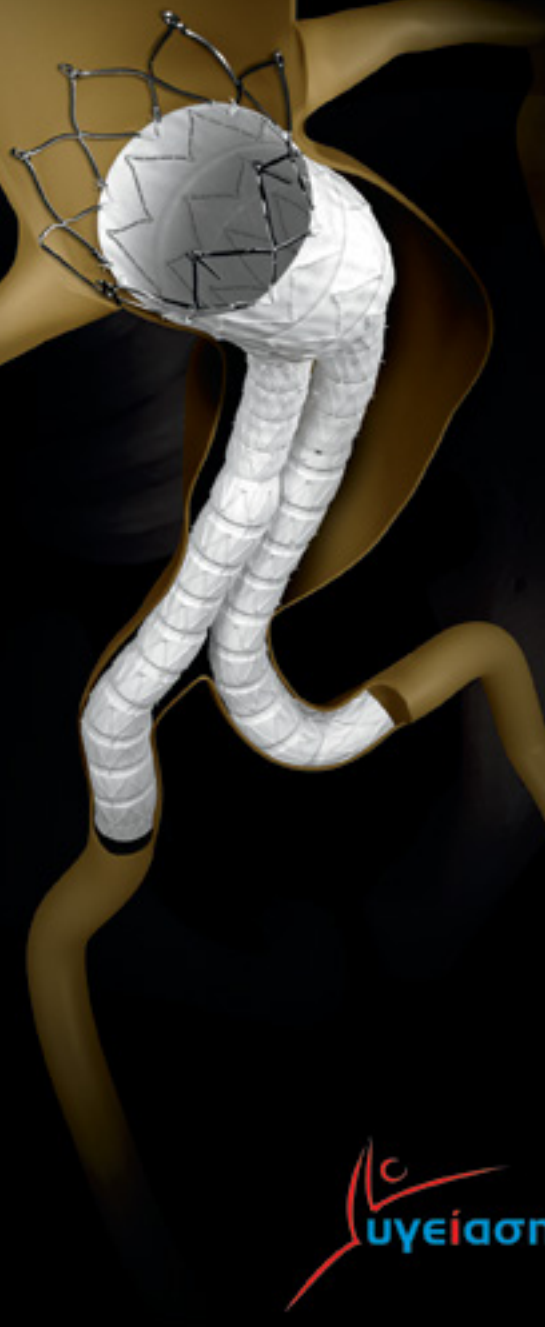

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Nonanastomotic aneurysms caused by Dacron degradation in a femoro-popliteal bypass graft

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Abstract:

Nonanastomotic aneurysms of synthetic femoro-popliteal grafts caused by material degradation are extremely rare complications, with most of the reported cases dating back to the 70s and 80s. We report a case of an 82-year-old man presenting with a large pulsatile mass in his mid-thigh, 22 years after a femoro-popliteal bypass had been performed with the use of a polyethylene terephthalate (Dacron) graft. CT angiography revealed the presence of multiple nonanastomotic aneurysms along the femoro-popliteal graft, the largest of which measured 106 mm in diameter and was located in the middle of the graft. The patient was operated on with the graft being ligated proximally and distally and replaced with a new PTFE graft.

INTRODUCTION

Most common complications related to synthetic grafts, used for peripheral arterial disease, include low patency, infection, and paranastomotic pseudoaneurysms.[1] True aneurysms of synthetic femoro-popliteal grafts caused by material degradation are extremely rare complications.[2] Most of the reported cases date back to the 1970s and 1980s.[3-15] Structural failure occurs sporadically and is a potentially serious complication that may be overlooked as it usually occurs at least 5 years after implantation.[2] Synthetic grafts are unable to mimic the elastomechanical characteristics of the native arterial tissue.[16] One could advocate that the manufacturing process of synthetic grafts has improved since, and that modern grafts are more resistant to mechanical and structural fatigue, as well as to in vivo material degradation caused by the contact with biological fluids. In fact, the last reported case of a true aneurysm in an infa-inguinal bypass graft was in 2002.[2]

We report a case of multiple nonanastomotic aneurysms of a polyethylene terephthalate (Dacron) femoro-popliteal graft 22 years after the bypass was done. We also review the literature focusing on the factors, namely mechanical stress and in vivo bio-degradation, contributing to the aneurysmal degradation of synthetic grafts.

CASE REPORT

An 82-year-old man presented to the emergency room with a large pulsatile mass in his right thigh, complaining of increasing pain and discomfort (Figure 1). The mass had been there for a few years and he was aware that he had an aneurysm. The mass had rapidly expanded during the last few days. The patient had undergone a right femoral to above knee popliteal artery bypass in 1996 for disabling claudication. An 8mm knitted Dacron graft had been used.

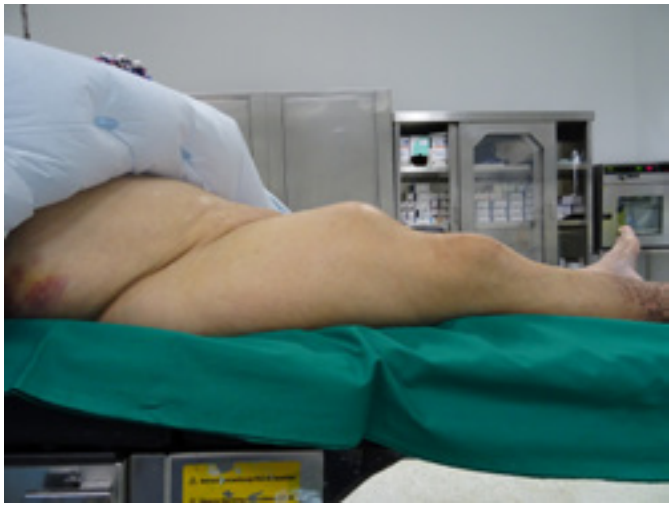

Figure 1. Photograph of the right limb of the patient depicting a large mass in the middle of his right thigh.

Past medical history included hypertension, stage IV chronic obstructive pulmonary disease (COPD), deep vein thrombosis (DVT) of his left leg and pulmonary embolism (PE) 6 months prior to this admission. He had been on oral anticoagulation with dabigatran following PE. He did not report any injury of his right thigh.

On examination, he was found to have a large pulsatile mass in his mid-thigh and palpable popliteal pulses. CT angiogram revealed a 106 mm in diameter aneurysm in the middle of the Dacron graft and several smaller aneurysms along the whole length of the graft (Figure 2). The bypass was patent.

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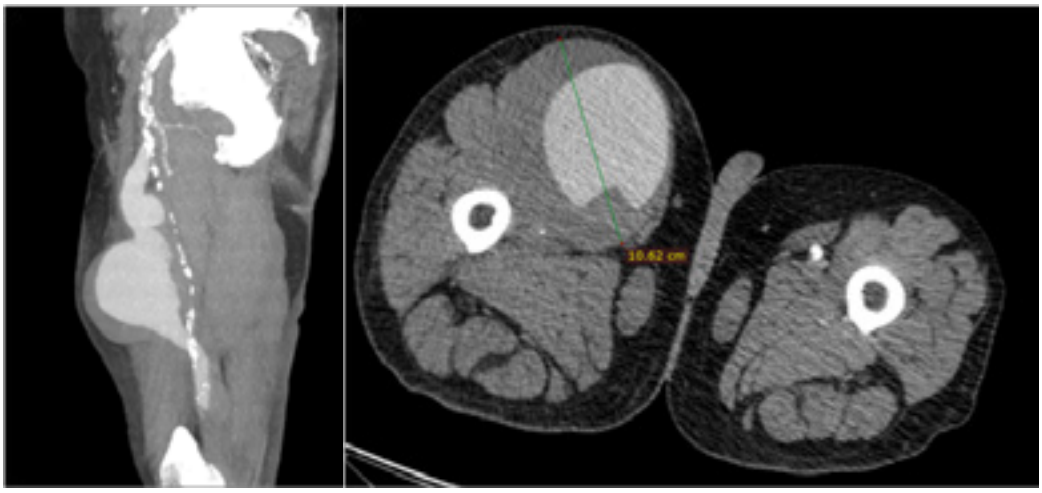

Figure 2. CTA depicting a 106 mm in diameter aneurysm in the middle of a femoral-popliteal bypass graft with the graft being patent.

The patient was admitted for an urgent operation. Dabigatran was discontinued and replaced with low molecular weight heparin.

The patient was operated under spinal anesthesia and sedation. Appropriate antibiotic prophylaxis was administered. The common femoral artery (CFA) was dissected and clamped proximal to the graft anastomosis and the popliteal artery was dissected and clamped distal to the graft anastomosis (Figure 3). Dissection was done, at an adequate length, to allow for a new anastomosis both proximally and distally. The graft and the aneurysm were partially dissected. The graft had dilated beyond structural capacity and had ruptured forming a false aneurysm within the adductor canal. This false aneurysm cavity was evacuated to relieve the pressure from the patient's thigh. Part of the Dacron graft was sent to the laboratory for bacterial culture and the rest was sutured to prevent back-bleeding from the native artery. A new polytetrafluoroethylene (ePTFE) 8mm graft was anastomosed to the proximal CFA and distally to the above knee popliteal artery. The tunnel made for the new graft was again through the adductor canal.

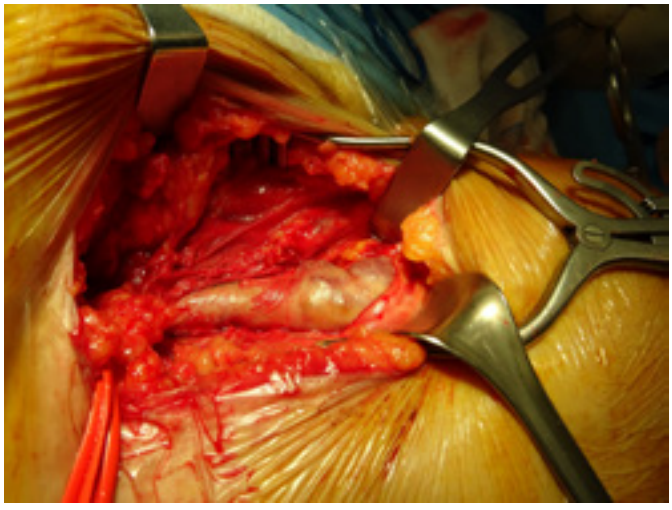

Figure 3. Surgical exposure of the femoral anastomosis and the first few centimeters of the graft. The aneurysmal degradation of the graft is evident.

Graft culture was negative for any microorganism. The patient made an unremarkable recovery and was discharged within 5 days.

DISCUSSION

The modern Dacron textile vascular grafts are not significantly different, from those introduced six decades ago, in terms of their structural geometry. This remains analogous to traditional textile structures rather than to an arterial vessel.[17] Compliance mismatch between native artery and a prosthetic graft used for infra-inguinal bypass is the most significant factor for graft failure.[18]

The innovation in modern Dacron grafts, from material and biomechanical aspect, is limited to the biological coating (internal compliant membrane - ICM) and decreased wall thickness that improve graft compliance.[18] Still, currently available vascular grafts exhibit more than four times reduced compliance in respect to native arteries.[19] Inability of mimicking the elastomechanical characteristics of the native arterial tissue, and the consequent lack of adequate compliance of the grafts, leads to dilation and true aneurysm formation.

Dacron grafts are continuously subjected to the pulsatile stresses of the blood flow that leads to mechanical fatigue of the filaments, as well as chemical and physical alterations associated with biodegradation. This may result, as in our case, to localized thinning and distortion of cross-sectional shape, bending and twisting deformation of the Dacron fabric. Finally, there is transverse transection of the filaments and the graft fails, forming an aneurysm.

Impressively, the number of similar case reports has significantly decreased during the last 20 years, at least for Dacron grafts used for peripheral arterial disease. This may be due to the fact that the ICM and the decreased wall thickness have improved graft compliance.[18] Nevertheless there is a clear need for development of alternative conduits that can effectively mimic the native biomechanical vascular properties. This is really relevant to aortic surgery where an inextensible graft segment could lead to prosthesis-related complications, as well as retrograde deleterious effects on valve competence,

and cardiac function.[16] New advances in tissue engineering of blood vessels that use elastomeric materials such as polyurethane[20,21] and silicone rubber[22] have not yet proved to be biostable. These materials may, in the future, be able to functionally integrate with the host tissue and induce a process of in vivo arterialization.

In conclusion, although extremely rare, true, nonanastomotic aneurysms of old but patent Dacron grafts may still occur and may rupture causing the formation of false aneurysms. Due to the rarity of this complication, surveillance for nonanastomotic graft aneurysms is not justified. However, vascular surgeons should be aware of this complication and suspect it in cases of pulsatile masses that develop along the course of old bypass grafts.

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Endovascular Repair of a Giant False Lumen Iliac Aneurysm Following an Acute Type B Aortic Dissection

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Abstract:

Endovascular treatment is the first-line intervention for a complicated acute type B aortic dissection; however, the ideal approach is still under research. We present a case of a 47-year-old patient who presented in the emergency complaining of intense pain in his left lower quadrant over the last 48 hours. His computed tomography angiography revealed a complicated acute type B aortic dissection that extended to his left common iliac artery where the formation of a 10.6 cm aneurysm of the false iliac lumen caused the entire collapse of the ipsilateral true lumen. Following the deployment of a thoracic stent graft, scaffolding was built on a later stage utilizing a bare metal stent for the visceral aorta along with a system of stentgrafts for the infrarenal aorta and the iliac arteries. The decompression of the false lumen and the exclusion of the aneurysm induced a positive aortic remodelling.

Keywords: Aorta, Dissection, Endovascular Repair, Stentgraft

INTRODUCTION

The treatment of complicated acute type B aortic dissection (cATBAD) is a complex procedure, as the frailty of the aorta and the extension of the disease preclude the open repair while the unique pattern of the dissecting membrane imposes an individual approach where various endovascular techniques are combined[1]. Herein, we present a quite challenging case of cATBAD where a mixture of the available contemporary endovascular techniques was enrolled to engage the elimination of the false lumen (FL). Informed consent was obtained from the patient before publishing his images and history; therefore, approval by the institutional review board was waived.

CASE PRESENTATION

A 47-year-old male patient presented to the emergency department, complaining of a sudden onset of intense pain in his left lower quadrant over the last 48 hours. Being a non-smoker and having no relevant medical history, his physical examination revealed a pulsatile mass in his left suprainguinal region and an absence of arterial pulses in his ipsilateral lower limb. However, arterial signals were audible upon Doppler ultrasound examination, and he was full ambulatory. Following an unremarkable blood exam, his ultrasound showed an aneurysm of his left common iliac artery; therefore, a computed tomography angiography (CTA) was conducted which exhibited a complicated acute type aortic B dissection (Figure 1a). Having the intimal tear at the distal end of the upper part of his descending thoracic aorta, the dissection had extended bilaterally up to his right common iliac artery (CIA) and left external iliac artery (EIA) respectively where the FL of his left common iliac artery had formed a giant aneurysm of 10.6 cm. The true lumen (TL) of his left common iliac artery was completely collapsed by the aneurysm causing the malperfusion of his left lower limb (Figure 1b). Regarding visceral and renal perfusion, it was maintained exclusively through the TL. The patient was haemodynamically stable with well-controlled blood pressure; however, taking into consideration the risk of impending rupture, a decision was made to urgently treat the patient following a consecutive approach. Hence, under general anaesthesia, on a first stage, his right common femoral artery (CFA) was exposed and after gaining access to the TL of his thoracic aorta, a tapered thoracic stentgraft 36-32x209mm (Zenith Alpha, Cook) was successfully deployed covering the proximal entry point of the FL (Figure 1c). Following the procedure, the pulsatile mass in his left suprainguinal region was still present upon physical examination and the pulses in his left lower limb were not restored; however, no ischaemic symptoms were noticed.

On a second stage, after five days, under general anaesthesia, according to the PETTICOAT (provisional extension to induce complete attachment) technique, an aortic bare metal stent (BMS) 46x186mm (Zenith Dissection, Cook) was deployed through his right CFA, in his thoracic aorta, covering proximally the last two struts of the previous stentgraft and landing distally to his infrarenal aorta. Subsequently, a semi-compliant molding balloon 46mm (Reliant, Medtronic) was consecutively inflated across the scaffolding, trying to

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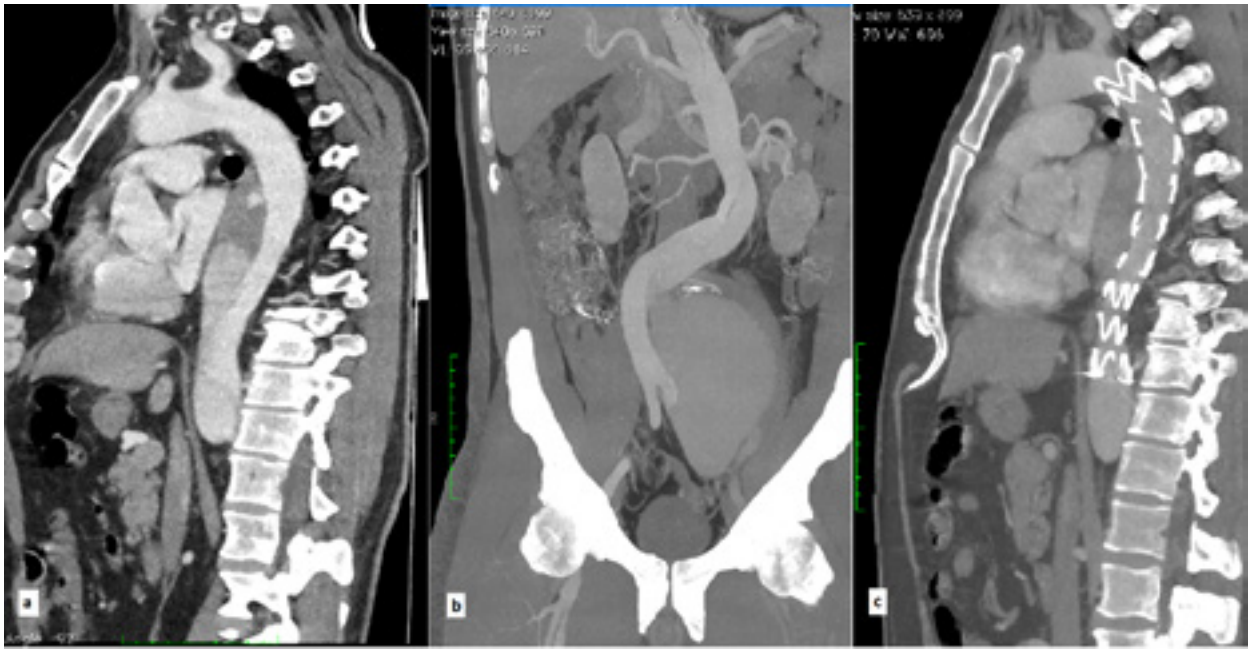

Figure 1. a) Preoperative Computed Tomography Angiography (CTA) on a sagittal plane. The intimal tear is located distal to the upper part of the descending thoracic aorta. b) Preoperative CTA scan on a frontal plane showing the 10.6 cm false lumen aneurysm of the left common iliac artery. c) Postoperative CTA scan. The thoracic stentgraft has sealed the entry point.

rupture the dissection membrane according to the STABILISE (Stent-assisted balloon-induced intimal disruption and relamination) technique. Then, a guidewire from his right CFA was advanced across the aortic bifurcation into the TL of his left CIA and was retrieved by his left CFA, using a snare catheter (EN Snare, Merit). Having access to the aortic TL from his bilateral CFA, an aortic cuff 28x58mm (Zenith Alpha, Cook) was delivered at his infrarenal aorta inside the distal part of the BMS and was followed by deploying a system of double D-shaped endografts 30x90mm (Altura, Lombard) which overlapped the aortic cuff, covered CIAs bilateral and reached his left EIA after the delivery of an iliac stentgraft extension 13x65mm (Altura, Lombard), similar to extended PETTICOAT technique.

The patient revived from the surgery; however, his pulsatile mass was not eliminated and although arterial signals were present upon doppler examination, his pulses distal to his left leg yet were not restored. A new CTA revealed a partial thrombosis of the proximal part of the FL; nonetheless, the persistent perfusion of the FL considerably constrained the expansion of the TL and still poured the aneurysm. Moreover, the left iliac extension was severely pressurized by the FL aneurysm inducing significant stenosis and a type Ib endoleak, at his right CIA, exaggerated the FL perfusion in combination with the patent lumbar arteries, at the level of aortic bifurcation (Figure 2).

Upon a third stage, under general anaesthesia, aortic stentgrafts 59x14mm (BeGraft, Bentley) were deployed by a kissing technique into the previous D-shaped endografts and a combination of balloon angioplasty 14x60mm (Atlas, Bard) along with stenting 13,5x40mm (Fluency plus, Bard), resolved the severe stenosis at his left iliac extension. Finally, the Ib endoleak was obliterated by deploying a bell-bottom stentgraft 16-27x100mm (Excluder, Gore) at the right CIA. Immediate after the procedure, the pulsatile mass was eradicated and the pulses to his left leg were restored.

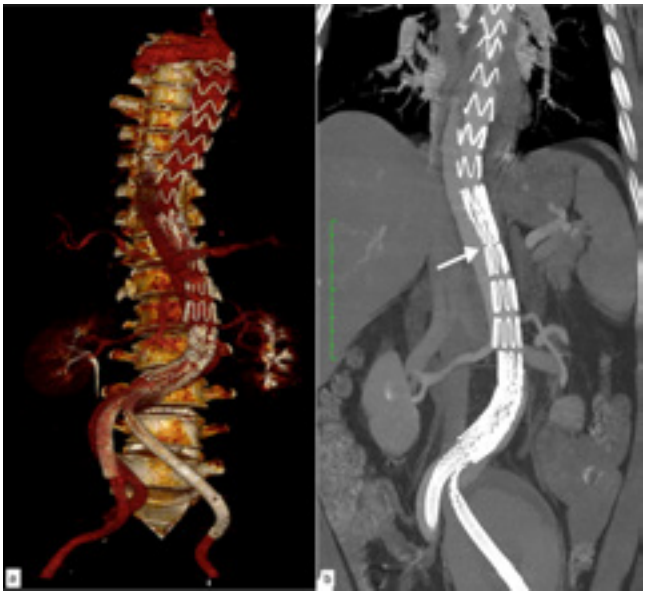

Figure 2. CTA scan after the second procedure. a) 3D reconstruction. The persistent flow in the false lumen is apparent and reinforced by the type Ib endoleak of the right iliac axis b) Frontal plane. The white arrow shows how the expansion of the true lumen is constrained by the false lumen. Other findings include the severe stenosis of the left iliac extension at the aortic bifurcation and the partial perfusion of the aneurysmal sac.

Following an unremarkable postoperative course, a new CTA showed adequate expansion of the aortic TL, depressurized FL with persistent flow due to his patent lumbar arteries and almost complete thrombosis of his aneurysm (Figure 3).

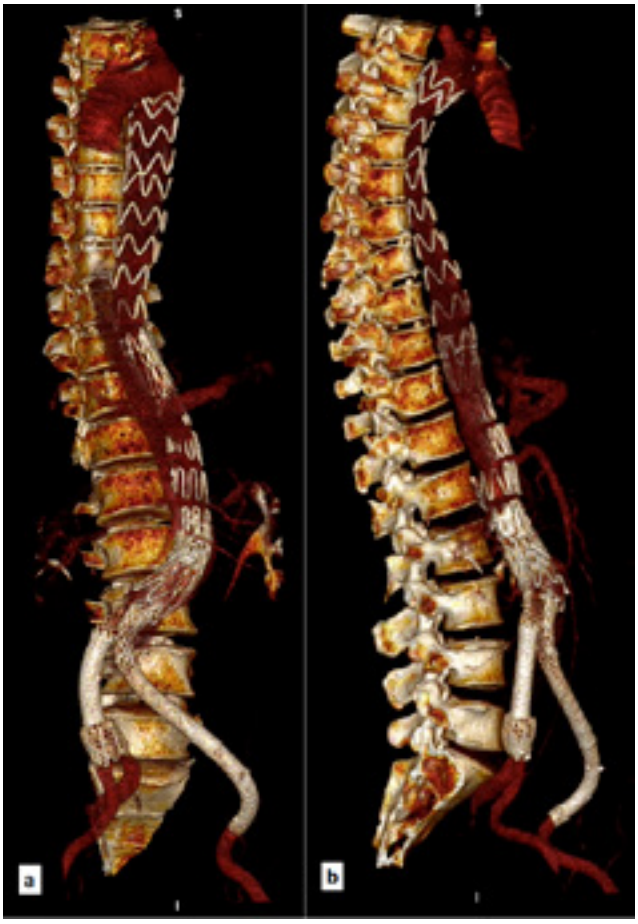

Figure 3. 3D reconstruction of the CTA after the final procedure. a) Frontal plane which exhibits the residual flow of the false lumen, the sufficient expansion of the true lumen and the exclusion of the left common iliac aneurysm. b) Right lateral view showing the positive aortic remodelling.

Upon a nine-month follow-up, the patient remains asymptomatic. Duplex scan failed to show perfusion of the aneurysm and a new CTA exhibited a positive remodelling of the aorta where the total volume of the aneurysmal sac has significantly reduced (Figure 4). Nevertheless, the persistent slow flow of the FL necessitates vigilance and regular surveillance.

DISCUSSION

Complicated acute type B aortic dissection (cATBAD) is a rare, albeit lethal condition. The reported incidence of type B aortic dissection is 15 per 100,000 patients per year and 25% of the acutely presented are complicated with the in-hospital mortality being as high as 50%[2]. Although the reported risk factors for inducing an intimal tear are mainly arterial hypertension, advanced age, previous aortic pathology and drug or strenuous activity which induce increased shear stress, none of the aforementioned was related to our patient's history. Given his age, an underline connective tissue disorder is possible[3].

There has been a consensus that thoracic endovascular repair (TEVAR) should be the initial approach for cATBAD with the open repair being the alternative option[2]. However, there has been recently an increasing amount of evidence supporting that adjuvant techniques are necessary to promote optimal aortic remodelling[4]. TEVAR can seal the proximal entry tear and considerably decrease the pressure of the FL by redirecting the blood flow into the TL. Therefore, the size of the TL will be restored, and the FL will be thrombosed. However, the formation that the distal aorta will follow after TEVAR is unknown since the FL usually extends to the abdominal aorta and across the aortic bifurcation like in our case. It is also known that in most cases, several intimal defects across the aorta preserve the FL flow[5]. Moreover, the continuous oscillation of the dissecting lamella, following the cardiac cycle impedes the FL thrombosis. Persistent flow into the FL in the absence of a reentry point or outflow vessels would cause the rapid growth of the aortic diameter which is consistent with the evidence supporting that partial distal FL thrombosis is an independent predictor of late mortality[6].

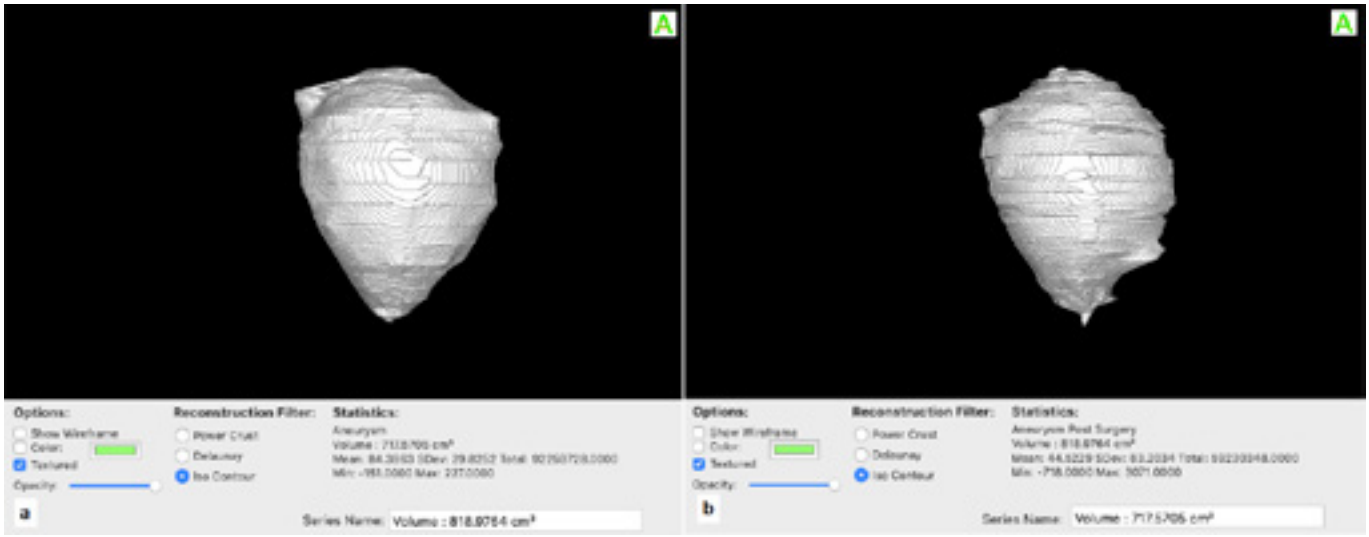

Figure 4. Segmentation of the false lumen common iliac aneurysm and comparison of the volume of the Region of Interest (ROI). a) On the preoperative CTA scan, the volume of the aneurysm is 818.97cm^3. b) On the 9-month follow-up CTA scan, the volume of the aneurysm has considerably decreased at 715.57cm^3.

Bertoglio et al. reviewed the recent literature regarding the use of the PETTICOAT technique and demonstrated overall 30-day mortality of 4,9% and 90.2% clinical success. Although TL and FL significantly and favourably altered across the studies, the FL continued to decrease in the thoracic aorta but remained stable in the abdominal aorta[7].

Regarding our case, following the initial TEVAR, we deployed an aortic BMS distal to the thoracic stentgraft supporting the TL and fixing the lamella against the wall of the FL. The inflation of the semi-compliant balloon inside the stents attempted to increase the fixation by rupturing the dissecting membrane which is known as STABILISE technique. Melissano et al. assessed the latter technique in a case series reporting encouraging outcomes by comparing the preoperative with the postoperative volumes of the TL and FL in the follow-up[6].

Trying to address the remodelling of the aorta beyond the aortic bifurcation, we utilized a modified type of the extended PETTICOAT technique that Kazimierczak et al. had recently described[5]. They presented in a case series of 17 patients with cATBAD, the deployment of parallel stentgrafts at the aortic bifurcation to increase the infrarenal radial force of the previously implanted aortic BMS, seal the distal entry points and promote the relamination of the membranes in the common iliac arteries. We slightly change their technique and by being more similar to the covered endovascular reconstruction of aortic bifurcation (CERAB) technique, an aortic infrarenal covered stent was deployed inside the BMS and was followed by a system of D-shaped endografts at the level of aortic bifurcation which helps to endure the expansion of the TL with fewer gutters and better haemodynamic behaviour[8]. However, a second pair of kissing stentgrafts was also necessary to fully expand the infrarenal aortic TL and along with the ballooning and stenting of the left iliac extension counteracted the pressure of the FL.

Our patient remains asymptomatic after nine months of the procedure. His last CTA revealed persistent slow perfusion of the sac in a delayed phase similar to type II endoleak and as is already recommended by the guidelines, life-long imaging surveillance is essential to reassure the optimal aortic remodeling[2].

CONCLUSION

Cases of complicated type B aortic dissection tend to have unique anatomical characteristics which necessitate an individual approach. Careful planning and proper adoption of the available techniques will promote the desirable aortic remodelling which still evolves after the treatment making the surveillance a crucial aspect of the total management.

Prior presentation: The current case report was presented online, on 14/12/21, at a meeting of the Hellenic Society of Vascular Surgery (HSVES iMeeting)

Acknowledgements: None

Conflict of Interest: None declared

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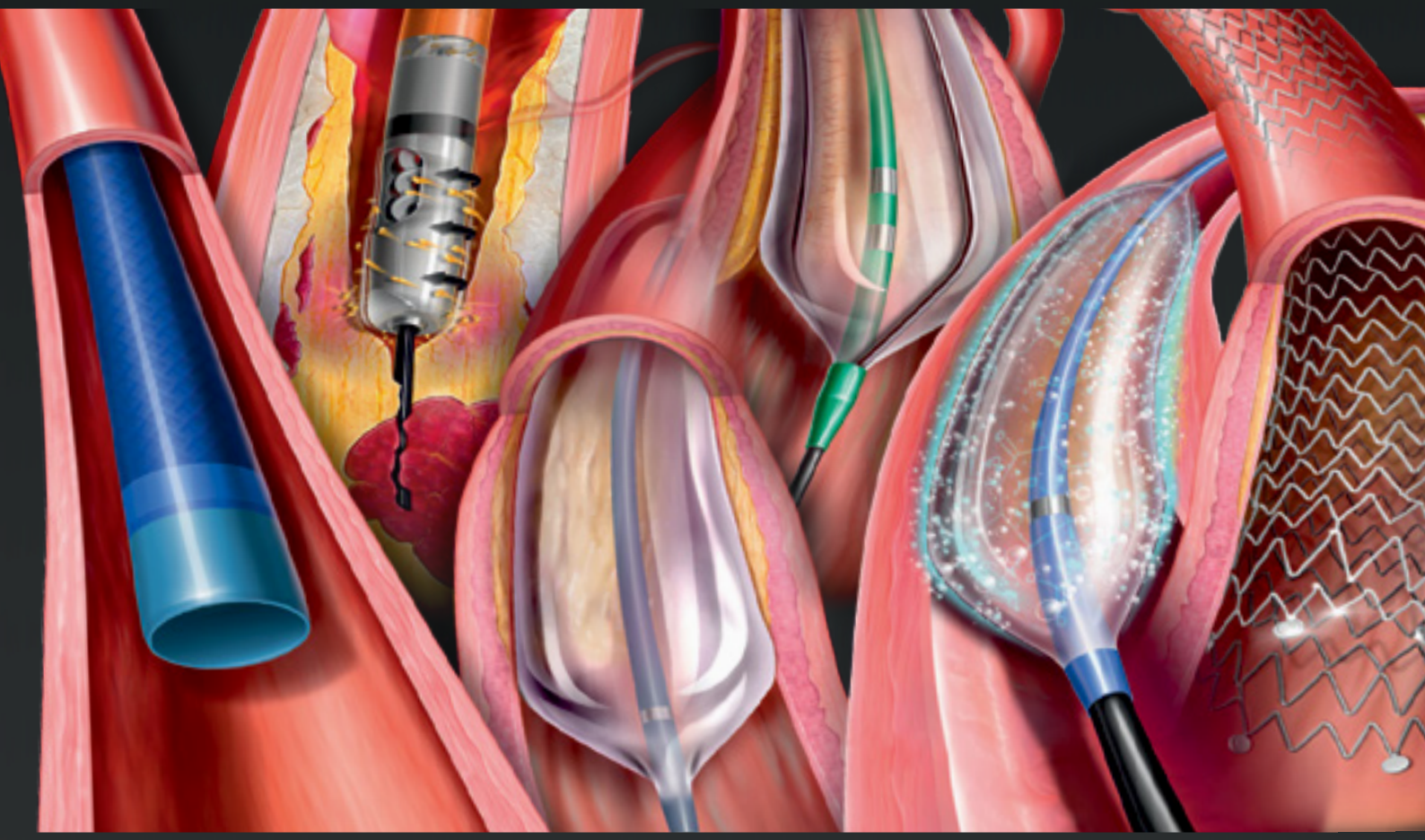

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Superior Mesenteric Artery Stent Fracture: A case report

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Abstract:

Over the past decades, endovascular repair of mesenteric ischemia (MI) has gained grounds over traditional surgical repair. Despite its initially promising results, complications such as stent fractures can occur. In defiance of the low reported rates of stent fractures and in the face of the ever-growing number of patients treated endovascularly the need to establish a treatment strategy in dealing with stent related complication is evident. Here we report our experience of a superior mesenteric artery (SMA) stent fracture successfully treated with the use of a stent graft.

Keywords: Superior mesenteric artery, Stent fracture, Endovascular repair, Mesenteric ischemia

INTRODUCTION

Mesenteric ischemia (MI) is a rare medical condition which is responsible for about 0,1% of hospital admissions, with high mortality rates. Its pathophysiology includes inadequate blood supply, inflammatory injury and eventually necrosis of the intestine wall. In particular, chronic mesenteric ischemia (CMI) is of atherosclerotic aetiology in about 95% of cases. Its presentation lacks of specific clinical or raucous signs, therefore the diagnosis is difficult to establish at an early stage. Valuable diagnostic techniques for diagnosing CMI are digital subtraction angiography (DSA), computed tomography imaging (CT), magnetic resonance imaging (MRI) and mesenteric duplex ultrasonography (US)[1].

Endovascular revascularization has been favoured over open surgery repair due to lower morbidity, mortality, and shorter hospital stay. Although endovascular approaches have been questioned for their long-term efficacy, recently published studies have demonstrated the long-term superiority of percutaneous mesenteric artery stenting (PMAS) over traditional surgical techniques. The aim of this report is to present our experience of a patient who had PMAS of the SMA and readmitted to our department because of stent fracture[2].

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CASE REPORT

A 56-year-old male patient was referred to the Vascular Surgery outpatient department due to symptoms of peripheral artery disease and chronic bowel ischemia. The patient reported prior endovascular repair of abdominal aortic aneurysm and diminishment of his pain-free walking distance to less than 100 meters over the last two months. Additionally, he reported postprandial discomfort and pain a few hours after eating. On clinical examination, we detected the absence of left femoral artery pulse, which showed proximal arterial obstruction. His ABI index on the left lower limb was 0.35. An abdominal and pelvic CTA scan was performed depicting thrombotic occlusion of the left iliac limb and significant stenosis in both the coeliac axis and superior mesenteric artery. We proceeded with endovascular repair of left iliac limb occlusion and SMA stenting.

In the operating theatre, the lesion could not be crossed either by antegrade access, through the brachial artery, or by retrograde access through the left femoral artery. Our initial method is to attempt to gain access through the femoral artery, when the angle is not to steep. Otherwise, our preferable option is brachial access, but here it was not possible. The operators performed a right to left fem-fem bypass with a PTFE ring supported 8mm graft and subsequently an SMA stenting using the right femoral artery for access. We used a balloon-expandable 8x56 mm stent. The final angiogram depicted a fully expanded patent stent in the superior mesenteric artery. The patient was discharged two days after the procedure with an ABI index of 0.97 and remission of bowel ischemia symptoms.

On the first appointment of the follow-up period, the patient complained of persistent postprandial discomfort. He immediately underwent an abdominal x-ray which raised the suspicion of SMA stent fracture, a fact consolidated upon per-

forming a new abdominal CTA (Figure 1) (Figure 2) (Figure 3) (Figure 4). Because of the emerging risk of SMA thrombosis, the patient was planned for OR. The procedure was performed under local anesthesia. A 7 Fr -45cm Arrow sheath was placed in the left axillary artery with the final tip at the ostium of the SMA stent. Angiography showed the high-grade stenosis and fracture of the stent. The lesion was crossed with a 0.035" stiff Terumo™ guide-wire. We decided to bridge and cover the two parts of a stent with a Bentley BeGraft 9 x57 mm stent. Angiography after stent placement showed the absence of residual stenosis and very good flow. The SMA remained intact without the obstruction of any branch. After the successful completion of the operation we managed to suture the artery with 6-0 prolene suture. There were no peri- or postoperative complications and the patient was completely asymptomatic after the procedure. The patient was discharged the next day on dual antiplatelet therapy (Salospir 100mg & Plavix 75mg for 1 month and therefore continuation only of Plavix) and underwent a follow-up CT scan 3 months later depicting patent SMA stent graft.

DISCUSSION

Superior mesenteric artery is the main blood supplier to the intestine. In cases of SMA stenting the extensive shear stress caused by the high-pressure blood flow, the mechanical stress during motion movements and compression forces during the respiratory cycle are speculated to enhance stent deformity and even rupture.

The endovascular treatment has been established as the favourable technique for CMI because of excellent short and long-term outcomes regarding its safety and efficacy while concomitantly allowing for potential surgical or endovascular re-interventions in cases of stent related complications such as incidents of restenosis. Furthermore, due to high peri-operative mortality associated with open mesenteric bypass (up to 50%) in combination with patient co-morbidities, our initial attempt is the endovascular first-approach.

SMA stent fracture is uncommon, with few reports in the English literature. The lack of reported incidents and case control trials don't allow for conclusions to be drawn regarding a

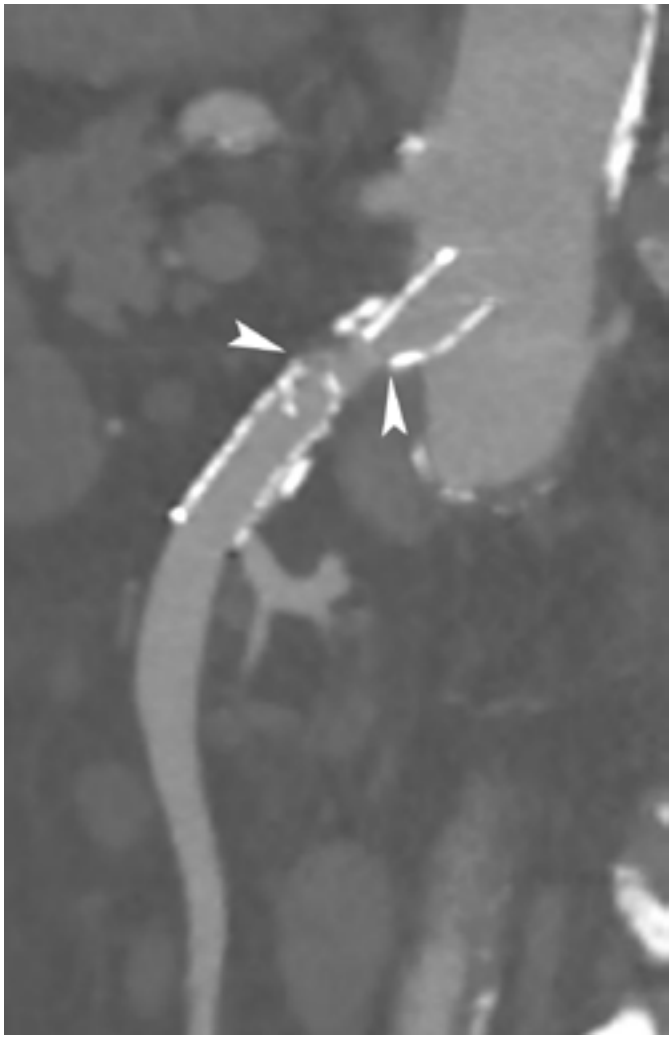

Figure 1: Curved multiplanar reformatted image (MPR) showing the centerline lumen of the superior mesenteric artery. Note the displaced wall calcifications, the hyperdense stent and the discontinuity (outlined by the arrowheads) representing the stent fracture

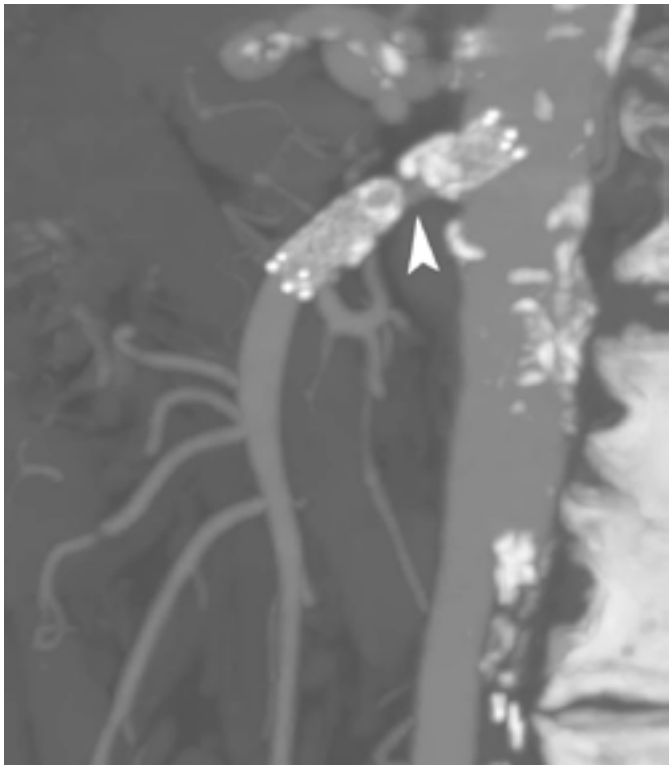

Figure 2: Thick slab Maximum Intensity Projection (MIP) image confirming the stent fracture (arrowhead).

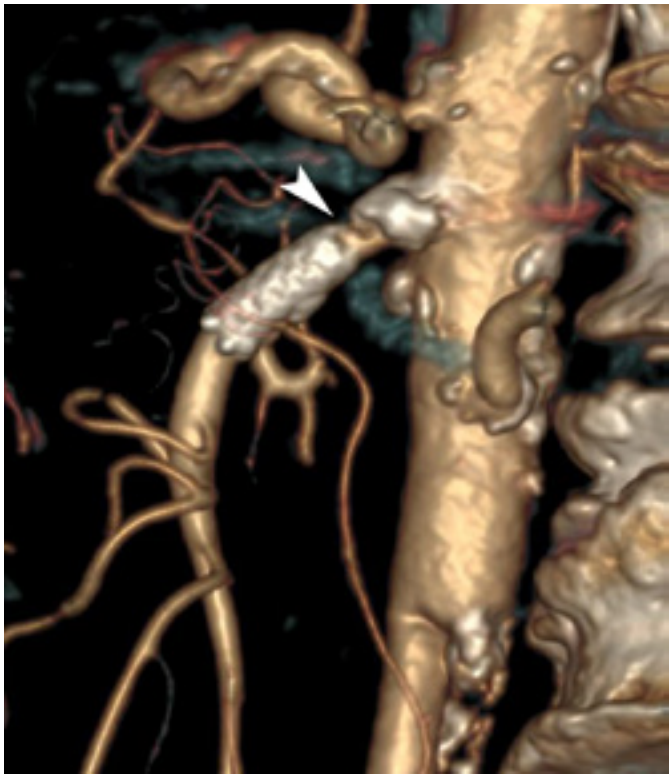

Figure 3: Volume rendering image better visualizing the findings in three dimensions

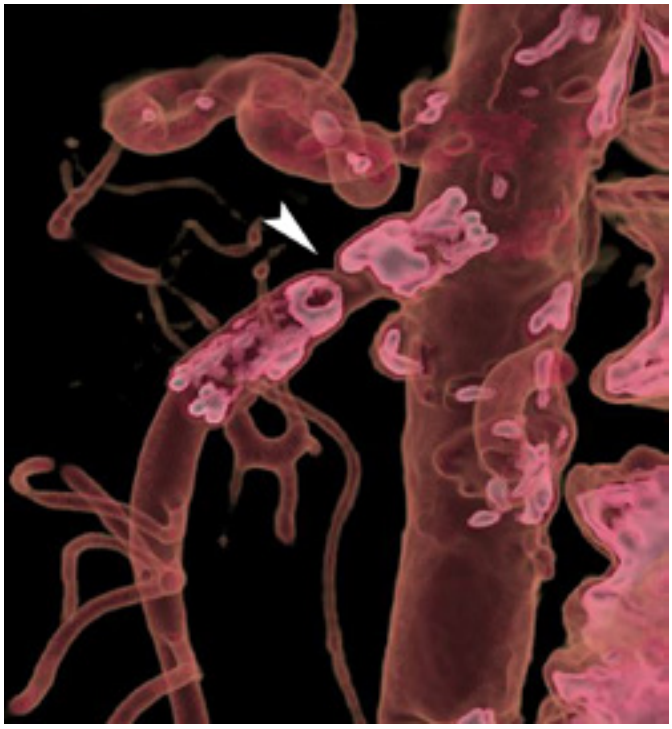

Figure 4: Transparent volume rendering image better visualizing the findings in three dimensions

definite mechanism leading to stent distortion. Nevertheless, stent material, design and characteristics (self or balloon expandable), as well as the patient's anatomy, seem to play a pivotal role in fracture occurrence.

Regarding our patient, initially a balloon expandable stent was placed in the SMA to treat the superior mesenteric artery occlusive disease with successful short-term results and an uncomplicated perioperative period. During his routine re-evaluation and while the postprandial symptoms persisted, it was found out that the stent in SMA was fractured. According to stent fracture classification presented by Allie et al. our device sustained a type III fracture[3]. Eventually, we placed an additional stent, without facing major technical setbacks applying the stent-in-stent technique. This time, in fear of future device fractures and loss of stent integrity, we favoured the use of a stent graft.

Stent fractures are more common regarding the stenting of superficial femoral artery (SFA), and this is due to the mobile nature of the SFA, especially in its distal portion inside the Hunter's canal where the vessel is subject to compression and bending forces.

The mechanism by which our stent failed to support the patency of the vessel could not be identified. Robins et al. in their publication of recurrent SMA stent fractures where they also used a balloon expandable stent which too suffered a fracture type III, respiratory cycle and diaphragmatic movement- in our case was not found any diaphragmatic massive hypertrophy from initial CTA- was identified as the ethology for repeated stent fractures[4]. Similar fracture morphology with (Type IV) or without (Type III) device migration as well as device preference (balloon expandable stents) is described by several authors regarding SMA stenting, suggesting a consistency in fractures patterns that is open to interpretation[5-7]. In particular regarding stent selection, Sharafuddin et al. in their publication dating almost two decades back, have advised against the use of balloon expandable stents in the SMA in fear of stent crushing due to external compression forces[8]. For the time being, we are in anticipation of the results by the Co-BaGI randomized control trial comparing covered stents and bare-metal stents for the treatment of CMI[9].

Despite the initial excitement, the overall improved safety and shorter length of hospitalization, endovascular treatment of chronic mesenteric ischemia has not yet live up to the initial expectations with primary patency and perioperative mortality rates directly comparable to surgical repair while high early restenosis rates produce skepticism[10].

CONCLUSION

Endovascular treatment of SMA stenosis is a viable alternative to surgical repair. Stent fractures are early device complications that can be effectively treated with the stent-in-stent technique. Additionally, it is our belief that the philosophy around SMA stenting should mimic that of SFA stenting. The respiratory cycle, along with the repetitive diaphragmatic movements, constitutes the SMA a mobile vessel and it should be treated as such.

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When the solution is in front of our eyes

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A 72-year-old male was admitted with a five-year history of persistent chest pain. The patient referred to multiple hospitalizations with the cardiological work-up to be negative for any abnormality of the heart. As an incidental finding, a penetrating aortic ulcer (PAU; red arrow) and an aberrant right subclavian artery (ARSA; white arrow) were detected on computed tomography angiography (CTA; A). Percutaneous bilateral femoral access was established. Angiography indicated PAU in the mid-thoracic aorta. A 42x121mm Zenith Alpha (Cook Medical Inc; Bloomington, IN) thoracic stent was deployed just below the ARSA covering the PAU (red arrow; B). The pain was relieved immediately after the intervention. The patient remains free of symptoms one year after the procedure.

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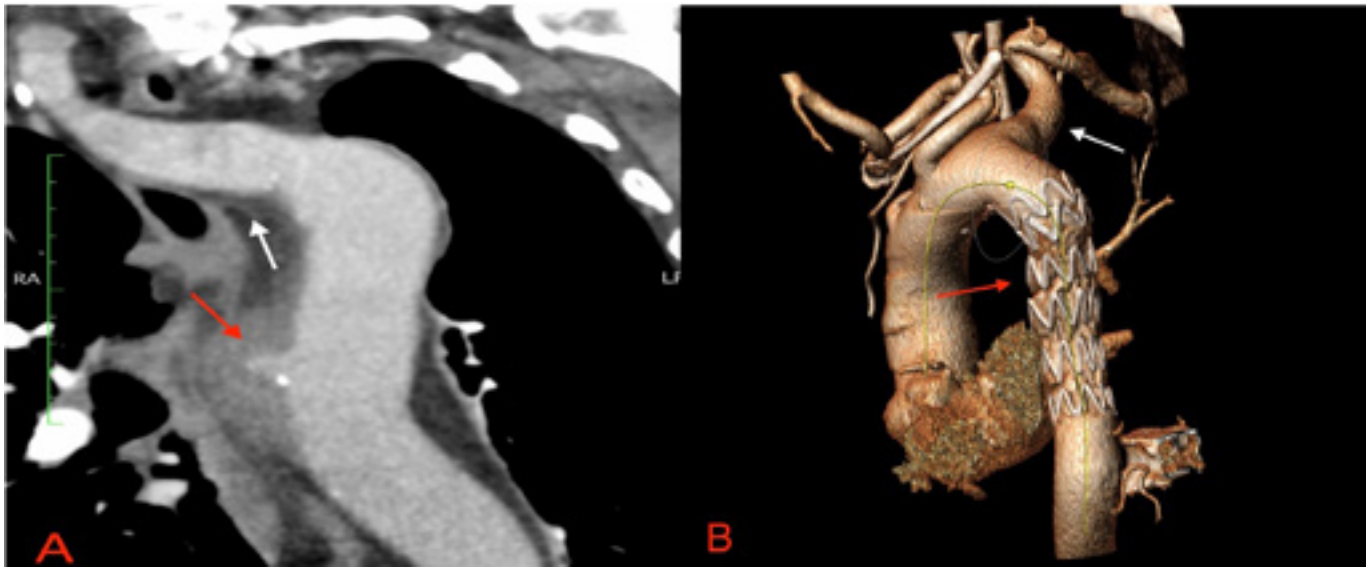

The *Chimney Rules* for a successful and durable treatment of complex aortic aneurysms by the chimney endovascular technique

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INTRODUCTION

The Jordan Rules was a successful defensive basketball strategy which developed by the Detroit Pistons and aimed to limit the effectiveness of Michael Jordan. The Jordan Rules were effective for the Pistons during their first three playoff meetings with the Bulls. Detroit beat Chicago four games to one in 1988 then defeated the Bulls in six games in 1989 and seven games in 1990. The Pistons won back-to-back 2 championships after eliminating the Bulls and stopping Michael Jordan. In a similar manner, the *Chimney Rules* aim to present in a comprehensive way the needed follow of parameters and key factors in a standardized manner in order to achieve successful and durable treatment of complex aortic aneurysms by the chimney endovascular technique.

The chimney technique after several in vitro studies can be indicated clinically in the emergent setting in ruptured or symptomatic cases when no time for manufacturing is available.[1-24] It can also be indicated for elective treatment. The anatomical featured include short infrarenal aortic neck (<1.5cm) and hostile neck anatomy when proximal sealing cannot be assured with standards abdominal devices. Also, in case of high tortuosity and calcification of the iliac vessels, precluding fenestrated technology for the treatment of pararenal aortic pathologies due to the risk of misalignment with the visceral vessels.[2] The chimney technique can be also used in type IA endoleaks caused by migration of previously implanted endograft. A prerequisite to employ chEVAR is to create at least 15mm of proximal sealing zone.[3] In case of need to overstent more than 2 target vessels, other complex EVAR techniques shall be considered since the PERICLES Registry experience denote that even though safe and feasible, the incidence of type IA endoleaks, chimney graft occlusions, and ischemic stroke rates is higher compared with the prevailing single chimney evidence.[4-13] The presence of extensive thrombus in the aortic arch or occluded subclavian arteries, 5mm or smaller in diameter renal arteries, wide neck diameter of more than 30mm or the lack of enough (20mm) sealing length are limitations for the technique.[4-13] The most remarkable lack regarding the use of the chimney technique is the absence of a standardized approach starting from the pre-operative planning, the procedure and follow up.

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CHIMNEY RULE 1:

PRE-OPERATIVE IMAGING EVALUATION

High quality preoperative thoracoabdominal and pelvic CTA of 1mm cuts is mandatory to accurately evaluate the anatomy of the aorta and its branches. It allows to understand the arch anatomy and type looking for safe navigation of catheters and sheaths through it in order to avoid cerebral embolization in presence of thrombus or type 3 arch, where the subclavian artery originates lower than the inner aortic curve. Access and reconstruction at a three-dimensional workstation/ program are needed to create centreline pathways and plan device sizing, selection and orientation for implantation. Regarding planning it seems that the chimney graft behaviour depends on the orientation of the renal artery. It seems like the stiffer a stent is, the bigger tendency it would have for the straight in line position. Thus, in downward oriented target vessels the balloon expandable covered stents when used as chimneys would show wide angles compared to the more flexible and mouldable SECS, while in 90º oriented transversely target vessels intending parallel positioning, they would be deployed in a more acute angles having a risk of kinking and stenosis.

CHIMNEY RULE 2:

DEVICE SELECTION

The PROTAGORAS study evaluated the standardized use of the Endurant II endograft (Medtronic, Minneapolis, MN, USA) in combination with the Advanta V12/iCAST (Getinge Group, Mijdrecht, the Netherlands) BECS in the renal arteries of 128 patients.[4] Consequently, this device combination received European CE mark approval as an on-label indicated therapy for juxtarenal aneurysms.[4] In addition, use of the Endurant device with the short M-shaped stents allows harmonic adaptability of the device in hostile necks, offering a full expansion of the endograft in 5mm length, covering the aneurysm sac and leading to successful exclusion of the pathologic process. Contemporaneously, the low-profile and flexible introducer system allows the trackability in severe iliac calcifications and

angulations.[13]

Regarding the chimney grafts, despite the plethora of options, the highest level of evidence has the Advanta V12 (Getinge) following by the Begraft peripheral (Bentley). Use of self-expanding covered stents such as the Viabahn (Gore) has good outcomes only when used with the Gore device as abdominal endograft. However, caution is required for the stainless-steel, balloon-expandable chimney grafts when lining angulated renal arteries with additional placement of flexible bare metal stents.[5] In those case, the Münster group observed a high risk of occlusion.[5]

CHIMNEY RULE 3:

OVERSIZING OF THE AORTIC STENT-GRAFT AND LENGTH OF THE NEW SEAL ZONE

The aortic stent graft oversizing is the first key parameter for ChEVAR planning. A 30% main graft oversizing is significantly related to freedom from IaEL-related reinterventions. In case of double chimney grafts and/or hostile neck features, the higher ranges should be planned. A 20-25 mm total neck length should be suggested considering the amount of lost neck, higher in angulated anatomies.[13] The pararenal and wide necks are significant risk factor for persistent endoleaks. A single parallel graft combination (Medtronic Endurant and Advanta-iCast V12) ensures excellent clinical mid-term outcomes also in hostile aortic necks. Wide necks (>30 mm) were significantly related to IaEL having a mean oversizing (OS) of less than 20%; contrariwise, narrow diameters (<23 mm) were significantly related to CG-stenosis/occlusion.[13] The presence of infrarenal neck of at least 2mm as in the IFU recommended resulted the only factor preventing IaELs; in case of no infrarenal neck, an oversizing more than 35% is needed in order to minimize the risk of persistent gutters.[13] Another important finding by Fazzini S. et al[13] was the estimation of the lost neck, considering that the ideal and available total neck length is not always achieved; even in case of very precise deployment, some portion of neck could be lost after placement of the endograft, caused by the presence of the sheaths in place and/or very angulated anatomy. Due to those reasons, a CTA-based measurement of the seal length in 3 segments including the infrarenal neck if present and the new neck is beneficial.[13] The mean diameter of these 3 segments should be taken in consideration in order to select the appropriate aortic stent-graft diameter based on the concept of 30% oversizing.[13] This is very crucial for durable outcomes especially in conical necks with divergence between the proximal and distal neck diameters.

CHIMNEY RULE 4:

PERIPROCEDURAL ISSUES

A kissing-ballooning manoeuvre should be always performed using a moulding compliant balloon and the balloons of each balloon-expandable chimney stent inflated to nominal pressure. First, the chimney graft balloon should be inflated followed by inflation of the Reliant balloon within the abdominal endograft. After that, the compliant balloon should be deflated followed by the deflation of the chimney graft balloon.

Another key point for the procedure should be the protection of the chimney graft balloon shoulder by the sheath. This manoeuvre allows a safe removal of the balloon avoiding any interaction with the pins as a possible cutting of the balloon and trapping the balloon by the pins.

CHIMNEY RULE 5:

Follow please Chimney rule 1,2,3 and 4.

CONCLUSION

The present letter to the Editor aims to review and present in a comprehensive way a more than 12 years published and clinical experience with the chimney endovascular technique in the treatment of complex aortic aneurysms. The view of the author is that the technique has a complementary role with the other total endovascular options and when there is an indication to use it, there is a need to follow rules, exactly like the Detroit Pistons have successfully done, when they planned to stop Michael Jordan, in order to be successful and achieve durable outcomes.

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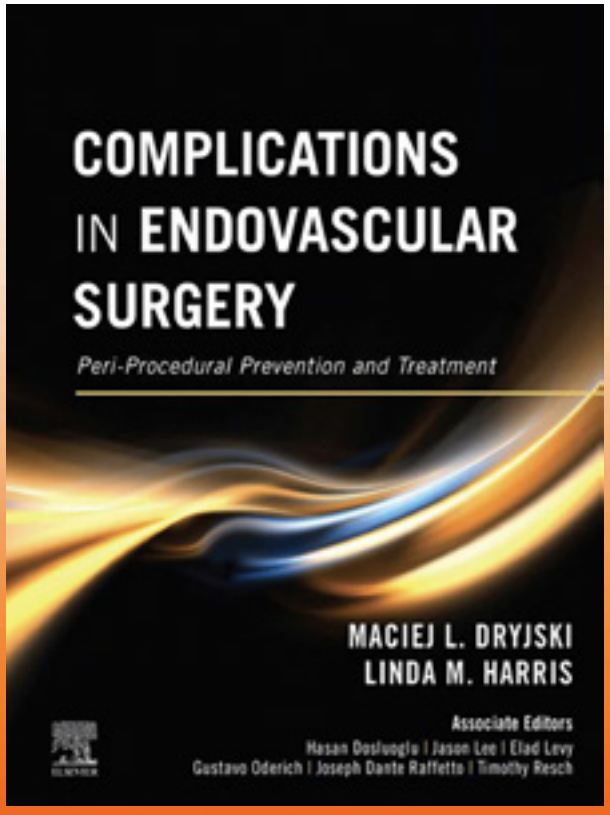

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