

**SPINAL PROTECTION DURING MANAGEMENT OF THORACIC
AORTIC PATHOLOGIES – RECENT EXPERIENCES WITH OPEN
REPAIR AND ENDOVASCULAR STENT GRAFTING**



THESIS

Submitted for the partial fulfilment for the requirement of the degree of

MCh in Vascular Surgery

By

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DIVISION OF VASCULAR SURGERY, DEPARTMENT OF CVTS

**SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL
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Travancore, an erstwhile province of pre-independent India, was ruled by Maharaja Sree Chitra Tirunal Balarama Varma until the country became independent in 1947. The Government of India took over the province after independence and was incorporated into the state of Kerala.

Known for their munificence, the royal family of Travancore considered themselves ‘dasas’ (servants) of Lord Padmanabha, the reigning deity of Travancore. Interestingly, they wore turban instead of a crown as a mark of respect to the Lord. Their philanthropy finds expression in their countless contributions to the country, then and now.

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DECLARATION

I, **AJAY**, hereby declare that the project in this book was undertaken by me under the supervision of Prof M. Unnikrishnan MCh, Professor and Head of Division of Vascular Surgery, Dept of CVTS, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram.

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CERTIFICATE

Certified to be the bonafide record of Dr AJAY, the work done at Vascular Surgery division, Department of CVTS, as part of MCh Programme in Vascular Surgery at Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram, for a period of three years from January 1st, 2013 to December 31st, 2015.

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TITLE

SPINAL CORD PROTECTION DURING MANAGEMENT OF THORACIC AORTIC PATHOLOGIES- RECENT EXPERIENCES WITH OPEN REPAIR AND ENDOVASCULAR STENT GRAFTING

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Introduction

Spinal cord dysfunction is unpredictable catastrophe which complicates surgical and endovascular management of thoracic aortic pathologies in 4% to 20% of patients. Although this catastrophic complication has lower incidence with increasing use of spinal cord protection adjuncts and with endovascular repair but remains unpredictable. Spinal cord paraplegia is associated with significant increase in mortality rate, requires intensive rehabilitation, and results in burden for patients, their families, and society. This serious complication is due to multiple factors and includes inadequate pre-existing vascular collateral network of the spinal cord, interruption to flow of blood, inadequate revascularization of significantly contributing spinal cord arteries during aortic reconstruction and increased cerebrospinal fluid pressure. Techniques to minimize spinal cord ischemia include limiting the aortic cross-clamp time, maintaining mean arterial pressure of $>90\text{mmHg}$, intraoperative and postoperative use of naloxone and steroids, epidural cooling of the spinal cord, systemic hypothermia, drainage of cerebrospinal fluid (CSF), distal aortic and viscerorenal arterial perfusion and reattachment of the critical intercostal arteries (based on intraoperative assessment of large radicular arteries in region of T8 to L1 or based on motor/somatosensory evoked potentials). We have used a host of strategies to reduce the risk of this formidable complication of management of thoracic aortic diseases in our clinical practice.



AIMS OF THE STUDY

- 1) To find out the incidence of post procedural spinal cord dysfunction following management of Thoracic aortic pathologies by Endovascular (thoracic endovascular repair) and Open repair technique.
- 2) To assess the efficacy of our management protocol in minimising spinal cord dysfunction.

Review of literature

Over the last 65 years we have witnessed the significant growth and development in the history of vascular surgery. Although earlier management of thoracic aortic pathologies like thoracic aortic/thoracoabdominal aortic aneurysm and aortic dissection were associated with significant mortality and devastating spinal cord dysfunction which over the time has improved by and large significantly across the globe, with use of multiple adjunctive strategies.

The danger of thoracic aortic surgery was documented early in vascular surgery history by Adams' landmark paper over aetiology of paraplegia and risk involved in thoracic aortic surgery, in which he described anatomy of spinal cord blood flow and the high mortality rate and paraplegia/paraparesis risk of 25% following repair of thoracic aortic aneurysms. A decade following this, M. DeBakey reported 50% mortality in small series of thoracoabdominal aortic aneurysm (TAAA) repair (1,2).

The modern era of surgical repair of TAAA started with E. Stanley Crawford, in his first published series in 1974 reported significant reduction in mortality and paraplegia rates achieved without assisted circulation (cardiopulmonary bypass). With lifetime experience of more than 1500 TAAAs, achieving an overall mortality of 8% and paralysis risk of 16%, Stanley Crawford set the benchmark standard for a generation of surgeons (3).

Despite of improved results reported from major centres in the modern era with mortality and paraplegia rates of less than 7% in elective surgeries (4), high mortality and morbidity continue to occur as demonstrated in two administrative database studies that documented 20% or higher elective mortality and high paraplegia rates in smaller, lower volume centres attempting treatment of these challenging and complex aneurysms (5).

Adams' paper linked the anatomic variations of spinal cord arterial anatomy to neurologic complications of aortic surgery by documenting the evolutionary desegmentation of spinal cord blood flow to a few intercostal radicular arteries in humans feeding into the single anterior spinal artery at multiple unpredictable intervals. Adams' study identified the greater radicular artery (Artery of Adamkiewicz/Arteria radicularis magna (ARM) between T8 and L2 spinal levels in 85% of humans) as most important because it supplies an especially important watershed area of the spinal cord in the lower thoracic aorta where there are fewer feeding radicular arteries and smaller anterior spinal artery (1).

Surgeons have focused primarily on an anatomic paradigm of paraplegia prevention for the last 6 decades by attempting to identify and reattach critical intercostal arteries. Complete paralysis prevention by this sole effort has failed, because experimental and clinical studies have demonstrated that blood circulation in spinal cord during aortic cross clamping (occlusion) for aneurysm repair is through collateral network of arteries, so that manipulation of physiologic parameters that affect the perfusion pressure in the collateral network, tissue oxygen delivery, and ischemic tolerance of the spinal cord neural tissue are more effective at preserving spinal cord function (5). Thus, although the cause of spinal cord ischemia is anatomic, the important neuroprotective strategies are physiologic.

The elegant and astute research into how the collateral network circulation responds to interruption of direct intercostal and lumbar artery blood flow has been done by Etz et al, he has described the concept of coaxial collateral network. In an experimental piglet model, they found that the more intercostal arteries were acutely interrupted, the greater the decline in collateral network pressure. More important, they found spinal cord blood flow and recovery of collateral perfusion pressure occur rapidly to 50% of preocclusion level within 24 hours and to near 90% within 72 hours, even with no open intercostal arteries(6,7).

The aetiology of spinal cord dysfunction is multifactorial, considering this context two different presentation of spinal cord ischemia has been noticed.

Acute paraplegia usually occurs immediately after surgery as patient awakens from anaesthesia. It could be a result of complete cessation of circulation through ARM or through patient's spinal cord collateral network (CN). Most common causes are: prolonged clamping of aorta without protective measures; inadequate distal perfusion; inadequate re-implantation of the intercostal arteries; exclusion of both hypogastric arteries and/or rarely embolic accidents. In the clamp and sew era, if thoracic aortic clamping lasted > 30 minutes, the risk of acute paraplegia significantly increased, and clamping > 60 minutes would certainly be the cause for acute paraplegia. Nowadays, in high volume centers, the acute paraplegia incidence, after the operative treatment of TAAA, is less than 3%. On the other side, the low percentage of acute spinal cord ischemia derives from high volume centers of excellence and represent only the small sample of patients. The real situation probably is more different (8).

Delayed paraplegia term is used when patient's neurologically assessment was normal as patient awaken from anaesthesia and spinal cord dysfunction develops after wards. The incidence of delayed paraplegia is not precisely established, while the complication itself can occur after a couple of days or even months after the surgery. Exact aetiology is not established and it is unclear which patients are more prone to develop it. Furthermore, the critical period for its development is also unknown. By looking at five patients, in whom delayed paraplegia was developed in range from one to 27 days, Maniar *et al.* recorded hypotension in three of them (9). Hypotension could be of a greater importance since it may lead to global hypoperfusion of the spinal cord. If delayed paraplegia occurs regardless the patency of the re-implanted intercostal arteries, this suggests that re-implantation may not be sufficient for its prevention but it could help creating backup system (10). It is possible that

during ischemia or spinal cord reperfusion, a form of insult is being developed, which would obstruct autoregulatory mechanisms and decrease hypotension tolerance.

Azizzadeh et al. has shown that value of postoperative mean arterial pressure (MAP) below 60 mmHg, non function of the CSF drainage catheter and haemoglobin value less than 8.6 g/L, can significantly affect the development of delayed paraplegia (11). Estrera *et al.* have noted that the aneurysm type, dissection and kidney insufficiency are the most important predictors of the delayed paraplegia development. The outcome for the patients with delayed paraplegia is significantly improved by cerebrospinal fluid drainage (CSFD). By combining CSFD, pressure optimization and tissue oxygenization, the success rate for the delayed paraplegia treatment is increased to 57% (12).

The main reason for the delayed paraplegia is probably the relative increase in cerebrospinal fluid pressure due to spinal cord edema. Affecting collateral network blood vessels, it decreases spinal cord perfusion pressure. This is why a significant number of patients respond well to CSFD. Fact is, in more than 50% of cases this does not happen, and it is a probable indicator for other reasons (hypotension, thrombosis, embolism, and hematoma) that cause delayed paraplegia. Reperfusion mechanisms also contribute to the development of delayed paraplegia. Following the establishment of the blood flow through the ischemic spinal cord as well as through all other tissues, oxygen and free radicals are released. Reperfusion leads to the inflammatory response followed by leukocyte adhesion to microvasculature and secondary release of inflammatory mediators. This cell damage, caused by reperfusion, behaves as debris that leads to occlusion of small blood vessels, thus increasing ischemia to spinal cord. Prolonged visceral ischemia is also of an importance. Namely, it causes the release of the inflammatory cytokines that additionally damage spinal cord (13).

Host of strategies are in use across the different centres of excellence, which is testimony for, none of the single modality is completely effective in preventive this devastating complication.

Literature describes number of strategies for reducing the spinal cord ischemia (reducing clamping time, sequential clamping and distal aortic perfusion), preservation of spinal cord blood flow (by preservation of subclavian, hypogastric arterial flow and critical intercostal artery implantation), increasing spinal cord tolerance to ischemia (moderate hypothermia, deep hypothermic circulatory arrest, regional epidural cooling and pharmacological protection), optimization of spinal cord perfusion (MAP>90, CSF drainage, prevention of steal phenomenon), early discovery of spinal cord ischemia (monitoring of motor evoked and somatosensory evoked potentials) and techniques for ischemic preconditioning of spinal cord (two stage procedures and minimal invasive segmental artery coil embolization (8)).

Stanley Crawford's Clamp and sew technique although used successfully in most cases (3), several studies confirm the need for an additional protective measure if the aortic cross clamp time is longer than 30 min (15, 16). Katz et al. reported a 71% incidence of spinal cord injury in patients with disease of the descending thoracic aorta and cross-clamp times longer than 30 min (17). Acher et al. with clamp and sew technique used cerebrospinal fluid (CSF) drainage and naloxone as additional protection, and reported low incidence of spinal cord dysfunction (18). Cambria et al. used the clamp and sew technique, with epidural cooling for protection of the spinal cord (19). Jex et al. reported risk of spinal cord injury reduced from 44% to 8% when distal aortic perfusion was used. Several techniques have been advocated to perfuse the distal aorta in a retrograde fashion. These methods include femorofemoral bypass, passive shunts, and left heart bypass. Femoro-femoral bypass with roller pumps has been used for distal aortic perfusion since the 1960s. Partial or total

cardiopulmonary bypass can be used to increase distal perfusion beyond the aortic clamps; however, this requires systemic heparinization. In a series of patients undergoing cardiopulmonary bypass for dissection of the aorta, 20%–30% suffered complications related to hemorrhage and one third of the deaths resulted from bleeding (20-21).

The Gott shunt (tube) has been used as a passive shunt (22); however, according to published reports of repair of traumatic tear of the thoracic aorta, the Gott shunt did not decrease the incidence of paraplegia associated with clamp and sew technique (23). Moreover, to minimize spinal cord injury, the distal aortic perfusion pressure required to be greater than or equal to 60 mmHg, which makes the Gott shunt less optimal technique for distal aortic and retrograde viscerorenal arterial perfusion.

The centrifugal pump (Biomedicus) is used for left heart bypass and it provides the best means of maintaining distal aortic and viscerorenal perfusion. By using centrifugal pump, flow can be regulated for maintaining distal mean aortic pressure of 60-70mmHg, less damage to the blood components compared with roller pumps, minimal heparinization is required, and a reservoir can be used in the setting of trauma or a ruptured aneurysm. Svensson and Loop has reported risks of paraplegia were 2.2%, 2.3%, and 5.8% with bypass, passive shunts, and the clamp and sew technique, respectively (24, 25). According to Kaplan et al. reported active distal perfusion achieved significantly greater distal aortic pressure than clamp and sew technique or passive shunting. However, use of distal aortic perfusion cannot prevent spinal cord injury completely. Distal aortic perfusion maintains blood flow to distal aorta, but if arteries supplying the anterior spinal artery arises from excluded segment of the aorta, the spinal cord will remain ischemic even if the distal aorta is perfused (26).

The anatomical features of the anterior spinal artery must also be considered because there is a variation in size between the anterior spinal artery above and below the junction of the Adamkiewicz artery and the anterior spinal artery (24, 27).

Preservation of spinal cord flow has two opposing theories, one is reimplantation is critical for reducing the spinal cord ischemia and contrary to this, evidence also exist for ligating all the intercostal arteries without any devastating consequences.

Ligation of patent T10 to T12 intercostal vessels was found to significantly increase the risk of neurological deficits after thoracoabdominal aneurysm repair when compared with vessel inclusion or pre-existing arterial occlusion from atherosclerotic disease (28). The rate of neurological deficits was 50% in the ligation group versus 12.9% in the reimplantation group and 9.9% in the group who had pre-existing occlusion.

Acher et al. reported excellent surgical results without reattachment of intercostal arteries. They demonstrated that quick oversewing of the intercostal arteries, with CSF drainage and naloxone administration, could help significantly to reduce the incidence of spinal cord injury (18). Griep et al. showed that reattachment could be avoided by ligating the intercostal arteries before aortic cross-clamping while monitoring somatosensory evoked potential. These reports signify that existing collateral network might improve the perfusion pressure (29). Spinal cord tolerance to ischemia is increased by hypothermia and pharmacological adjuncts. The basis of hypothermic protective effect consist of combination of reduced metabolism; inhibition of excitatory neurotransmitter (glutamate) release and decrease of superoxide anion production (30). Hypothermia of a spinal cord can be induced systemically or by regional techniques. Passive moderate systemic hypothermia (32-34 °C) is achieved by lowering the temperature in operating room (drift of temperature), and further by heat evaporation from large open surgical field.

Active moderate systemic hypothermia can be achieved by use of inline heat exchanger that as a part of atriofemoral (left heart bypass) or femorofemoral (partial) bypass. DHCA (15-18°C) was used first, in prevention of spinal cord ischemia in 1981. According to some studies, time span of 120 minutes, at 20°C enables normal spinal cord function.

Frequency of spinal complications during DHCA ranges 2% to 8% (31,32). Those who are advocate of DHCA, mention its advantages: bloodless surgical field, no need of aortic clamping and accessibility to the aortic arch. Enthusiasm for its use in TAAA surgery has gradually decreased due to common complications: coagulopathy, lung complications, cardiac complications and large third space loss. So its use is restricted to particularly Type-II TAAA, extensive aortic dissection and aneurysm encroaching the arch where clamping is difficult.

Cambria and Davison technique of regional hypothermia requires instillation of 4° centigrade cold perfusate in epidural space. By doing so, deep regional hypothermia is achieved (<20 °C), with decreased frequency of paraplegia to 10-11%. This technique requires two catheters. Local anaesthetic and cold infusion solution (4 °C) are placed through the first one that is placed in epidural space between T11 and T12 space. The second, 4-French catheter is placed in subarachnoid space between L3 and L4. It enables continuous monitoring of the spinal cord temperature and CSF pressure. The solution placement is initiated prior to aortic clamp placement, so as to bring the spinal cord temperature to 23–25 °C range before clamping. During the cold solution placement, CSF pressure rises rapidly, since drainage catheter is not being used, so values doubles than the initial ones are reached. This is the main drawback of technique, that is why the technique itself is employed only in a few surgical centers (33)

Acher et al. reported that naloxone (an opiate antagonist) with CSF drainage effectively lowered the incidence of spinal cord injury in patients undergoing thoracic and thoracoabdominal aneurysm repair (18). Svensson et al. showed that CSF drainage plus an intrathecal papaverine injection increased the spinal cord blood flow, inducing a protective effect against spinal cord injury (34). The role of corticosteroids in the prevention of spinal cord injury is controversial. However, the protective effect of steroids could be related to

stabilization of the cell membrane, modulation of the immune system, and action as a free radical scavenger.

True CSF Drainage value when protecting spinal cord from ischemia is difficult to estimate, taking into consideration the fact of its use together with other protective measures. Recent prospective randomized study of CSF drainage by Coselli et al. showed that CSF drainage reduces the spinal cord dysfunction particularly in extensive Crawford TAAA type-I and II significantly (35). Delayed paraplegia reversal after CSF Drainage, with recovery of spinal cord function of the rate of > 50% has been also reported in literature (36).

Somatosensory Evoked Potentials (SSEP) and Motor-Evoked Potentials (MEP's) are designed to monitor spinal cord perfusion. Cunningham et al. and Schepens et al. reported the usefulness of SSEP in lowering the risk of spinal cord injury in patients undergoing repair of thoracic and thoracoabdominal aortic aneurysm; however, SSEP monitoring has several limitations. First, SSEP tracings can be affected by some anaesthetic agents, hypothermia, and neuromuscular blockade effect; second, SSEP only evaluates the function of the dorsal sensory columns of the spinal cord; and third, there are reports of false-positive and false-negative results during intraoperative monitoring of SSEP (37,38). On contrary, MEP, that is frequently used nowadays, estimate function of motor neurons in anterior horns of the spinal cord. This method requires special anaesthesiology protocol due to the fact that complete neuromuscular blockade does not allow necessary level of motor activity which is required for MEP monitoring. Decrease of MEP amplitude to more than 50% of the initial value after aortic clamping, in the span of 5 minutes, is indicative of potential development of irreversible spinal cord ischemia. Should MEP decreases in the phase of segmental aortic clamping, it is necessary to raise proximal MAP over 80 mmHg, and distal aortic pressure over 60 mmHg. The loss of MEP after profuse retrograde bleeding from intercostal or lumbar arteries and its recovery immediately after occlusive catheter placement indicates steal

phenomenon and is managed by suture closure of refluxing arteries. Rapid loss of MEP, regardless of the bleeding, requires prompt revascularization of patent arteries in excluded aortic segment until MEP recovers. However, in case of MEP decrease, while the intercostal artery ostium is not visible, is it necessary to perform local endarterectomy, followed by re-implantation. This may not be the proof for MEP's usefulness, bearing in mind that no surgeon would look for intercostal artery ostium in case they are not visible. Finding of retrograde bleeding from intercostal arteries after endarterectomy and the MEP recovery after their reperfusion indicates that the intercostal arteries were connected to collateral network and spinal cord perfusion maintenance. After discontinuation of distal perfusion during the creation of distal aorta to graft distal anastomosis, MEP amplitude drops by 10% which suggests that pelvic circulation has a significant role in collateral network of spinal cord by hypogastric arteries. Application of this protocol has reduced the percentage of spinal cord ischemia to 3% (39).

The retrospective review suggests that paraplegia after open repair of extensive TAAA may occur significantly less when the repair is carried out in 2 stages rather than a single procedure. The interval in 2-stage repair allows stable remodelling of the inflow to whatever portion of the spinal cord is affected by segmental artery sacrifice during the first procedure before the collateral network is called on to provide enhanced inflow after the sacrifice of the remaining segmental arteries during the second stage. The precise time span between two operations is not known but according to Etz studies, recovery of the collateral network pressure to approximately 60% of preoperative levels occurs by 48 hours and appears complete by approximately 5 days after segmental arteries sacrifice (7, 40). In practice, surgeons usually perform second stage procedure after 3 to 4 weeks.

Minimal invasive segmental artery coil embolization (MISACE) is a promising new concept from Etz and co based on preprocedure endovascular priming to the arterial collateral

network and optimization of spinal cord perfusion before inevitable segmental artery occlusion occurs in TEVAR and most open single stage repairs. By doing selective, transfemoral segmental artery coil embolization it is possible to trigger for arteriogenic collateral network preconditioning, thereby allowing for recruitment of otherwise redundant arterial collaterals to the spinal cord collateral network. MISACE for successful collateral network preconditioning before conventional open or TEVAR may enable the safe repair of extensive TAA and TAAA as a one-stage operation. They performed procedure on two patients, one open surgery, and another one, endovascular intervention, with satisfactory results. Regardless the promising initial results two major issues remain: possible spinal cord ischemia development due to manipulation with guide wires (embolization, thrombosis), as for similar reasons spinal cord angiography was abandoned due to significant percentage of neurologic complications, and second one is an ethical problem (41).

After encouraging, initial results with TEVAR, first cases, and then, large series have been published with greater percentage of spinal cord ischemia than expected. In EUROSTAR with 443 patients managed with TEVAR, paraplegia occurred at 2.5% of the cases (42). Chiesa et al. in series of 103 TEVARs, have registered delayed neurological deficit in 4% of the cases, that, after the CFSD application, steroid therapy and correction of the system pressure values was successfully treated. It was noted that MAP value, lower than 70 mmHg, is a significant predictor for the occurrence of spinal cord ischemia (43).

Preventza et al., after analysis of 346 patients that have undergone TEVAR have found spinal cord ischemia in 4% (44). Its occurrence was significantly related to the female gender, length of the covered aortic segment and aneurysm extent. Khoynezhad and co have found that spinal cord ischemia was related to application of iliac conduit and covering of hypogastric arteries (45). According to EUROSTAR data, spinal cord ischemia incidence amounted 2.5%, while covering of the left subclavian artery (LSA), early surgical treatment

following the repair of abdominal aorta, kidney insufficiency and application of minimum three stents for covering the lesion contributed to its occurrence (46). Length of the uncovered part of distal aorta and distance from celiac trunk are also predictors of the ischemia development. More precisely, for every 2 cm of aorta above celiac trunk that is not covered, risk of spinal cord ischemia is reduced by 40% (47). Czerny et al. proven significant relation between spinal cord ischemia and covering of two or more vascular territories out of four existing (Left subclavian, intercostal, lumbar and hypogastric arteries). They have also pointed out the significance of hypotension (48).

Keeping in mind different mechanism of spinal cord ischemia development during endovascular procedures, as well as inability to reimplant segmental arteries, its prevention requires different strategies. Main preventive measures apart from optimization of mean arterial pressure which is similar to open surgical procedures, are revascularization of left subclavian artery as per standard indications described in literature and CSF drainage. There is no consensus when it comes to use of CSF drainage during TEVAR. Some would use it always, while some employ it selectively in cases where there is an evident risk from paraplegia development. In this selective group, some would use CSF drainage in strictly anatomically appropriate situations (we belong to this group), while others would employ this only after a patient displays features of spinal cord dysfunction (8).

Although the cause of spinal cord complication after surgery or endovascular therapies is anatomical but the treatment relies primarily on physiological parameters, as the increasing body of literature suggests.

Material and Methods

Over a period of 5 years from 2010 to August 2015, total of 116 patients including 54 patients who underwent open repair and 62 patients underwent endovascular repair of thoracic aortic pathologies were included in this retrospective study of prospectively collected data to look for spinal cord dysfunction in perioperative period. Pathologies treated included aneurysms of thoracic aorta/thoracoabdominal aorta/arch with descending thoracic aorta, aortic dissections and traumatic thoracic aortic injuries, both in elective and emergent setting. Endovascular repair for infra-renal abdominal aortic aneurysm and exclusive management of ascending aortic and arch pathologies were excluded from the study. Approval was obtained from the Technical Advisory Committee (TAC) and Institutional Ethics Committee (IEC) for the conduct of the study.

Demographics, preoperative, perioperative and postoperative data were recorded in a structured data collection sheet after reviewing patient records and institutional electronic medical records. Patients undergoing elective repair underwent diagnostic work-up with chest radiograph, computed tomography (CT) angiography and work up for fitness included, complete haemogram, renal and liver functions test, coagulation profile, pulmonary function test and basic cardiac work-up with electrocardiogram (ECG) and echocardiogram (Echo). All patients planned for open TAA/TAAA repair undergone coronary angiography (CAG) for risk stratification and coronary optimization if the significant lesion mandated intervention. Routine testing was abbreviated in patients who presented in rupture for conducting expeditious management.

Once decided for open repair/intervention necessary arrangements of blood and blood components were made during planning of procedures.

Renal insufficiency was defined as serum creatinine greater than or equal to 1.5mg/dl and increase of >0.5mg% was considered as renal failure in postoperative period. Coronary artery disease was defined as history of acute coronary syndrome, prior coronary angioplasty or CABG or indirect evidence of myocardial ischemic damage in ECG or Echo or coronary lesion confirmed on CAG .

Operative planning:

All patients underwent CT angiography, most of which were done using the institute's 256-slice Multidetector CT scanner. Axial, multiplanar reconstruction (MPR) and Volume-rendered technology (VRT) images were examined by the radiologists and exact measurements of length and maximum diameter of the aortic aneurysm, site of intimomedial tear/rent and luminal characteristics in aortic dissection, origin of viscerorenal arteries from true and false lumen and traumatic pathologies were recorded as well as the length and diameter of available landing zones for selecting the appropriate size of aortic stent-graft, considering an oversizing of 20% for aneurysmal pathologies, 10% for dissections and 10% in patients with connective tissue disorders. Measurements of the ilio-femoral vessels were also taken to check feasibility of access for TEVAR deployment.

Open Surgical Repair: Open repair of thoracic/thoracoabdominal aneurysm was done under general anaesthesia with double lumen endotracheal tube placed for better exposure of thoracic aorta and to avoid any damage to lung parenchyma. Nasogastric tube (Ryles tube) was placed in all patients for decompression of stomach during the procedure and also in postoperative period till Ryle's tube aspirate normalizes and bowel function returns. Urinary bladder was catheterized after induction of anaesthesia. Third generative cephalosporin(Cefoperazone) antibiotic was always given during induction of anaesthesia and used to repeat at 4 hours of open surgery.

Central venous pressure monitoring line either in internal jugular vein or subclavian vein, radial artery for proximal MAP and right femoral artery line for distal mean arterial pressure monitoring were placed in all patients. Proximal MAP was maintained at least 90 mm Hg and distal MAP was maintained 60 mmHg in majority of patients. Pulmonary artery Swan Ganz catheter were used in patients with some sort of cardiac dysfunction.

CSF drain (Fig 1) was placed in all patients either in L2-3 or L3-4 space using 4fr epidural catheter to measure the CSF pressure and keep the CSF pressure <10mmHg to increase the spinal cord perfusion pressure during the procedure and for 48-72 hours following the procedure. Maximum CSF drainage, in aliquots of 10-15 ml/ hr was done.

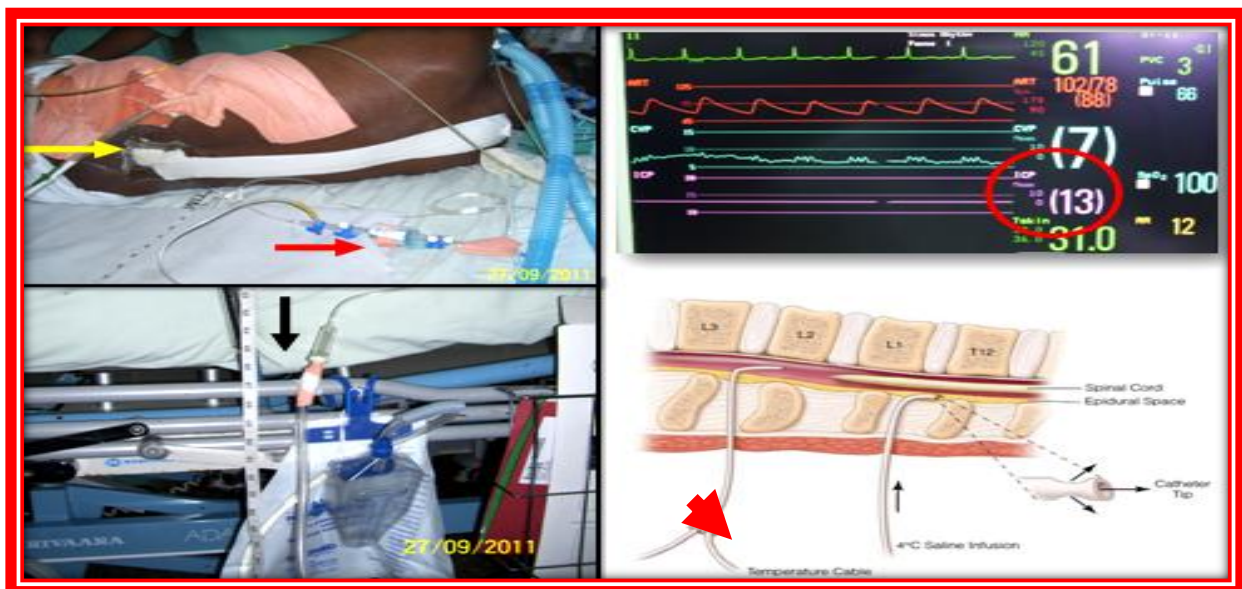


Figure-1- Showing the CSF drain(a), recording of CSF pressure on monitor(b), and site of catheter in subarachnoid space lower in the lumbar region to avoid any damage to spinal cord(c&d).

All patients received 30mg/kg IV Methyl prednisolone as pharmacological neuroprotection adjunct which was continued in postoperative period at dose of 5.4mg/kg for 24 hours.

Use of intravenous Sodium Nitroprusside was avoided during and in postoperative period to avoid any steal of blood from spinal cord collateral network for spinal cord protection.

All patients were positioned in right lateral modified Stoney's position, where chest will be 90° to table edge, abdomen 60° and groins from 45 to 30° to have better access to right femoral as well.

Thoraco-phreno-laparotomy approach was used for thoracoabdominal aneurysms with most TAAA-III, IV, V managed with proximal extent of incision in seventh intercostal space and distally extending over the costal margin and along the pararectal line to infraumbilical region as dictated by lower extent of aneurysm. In TAAA type-I, II a separate 4th space thoracotomy incision was used for proximal cross clamping of the aorta.

Left femoral artery exposure for distal aortic and retrograde viscerorenal arterial perfusion was achieved in standard fashion using the oblique incision placed over midinguinal point. Small 5 cm bit of 8mm dacron graft was anastomosed to CFA in an end to side fashion to have distal perfusion with temporary aorto-femoral bypass during the conduct of procedure. Distal graft attachment in end to side fashion to CFA will prevent prolonged ischemic injury to ipsilateral lower limb.

Aorto-femoral circuitry was made ready by one of the members of surgical team. For making the circuitry, two 35 cm each 3/8 inches CPB tubings were connected to each other by 3/8 and 3/8 channels of Y connector(3/8",3/8" and 1/4 Y" connector). 1/4" channel of Y connector was channeled to 1/4" 15 cm tube and which was further connected to Y connector with all three 1/4" channels. Two channels of Y connector were connected to 1/4", 10 cm tube. Finally from 1/4" tube end two Olympic connectors were attached and distally fixed with two Pruitt-Inahara shunts(Fig-2).

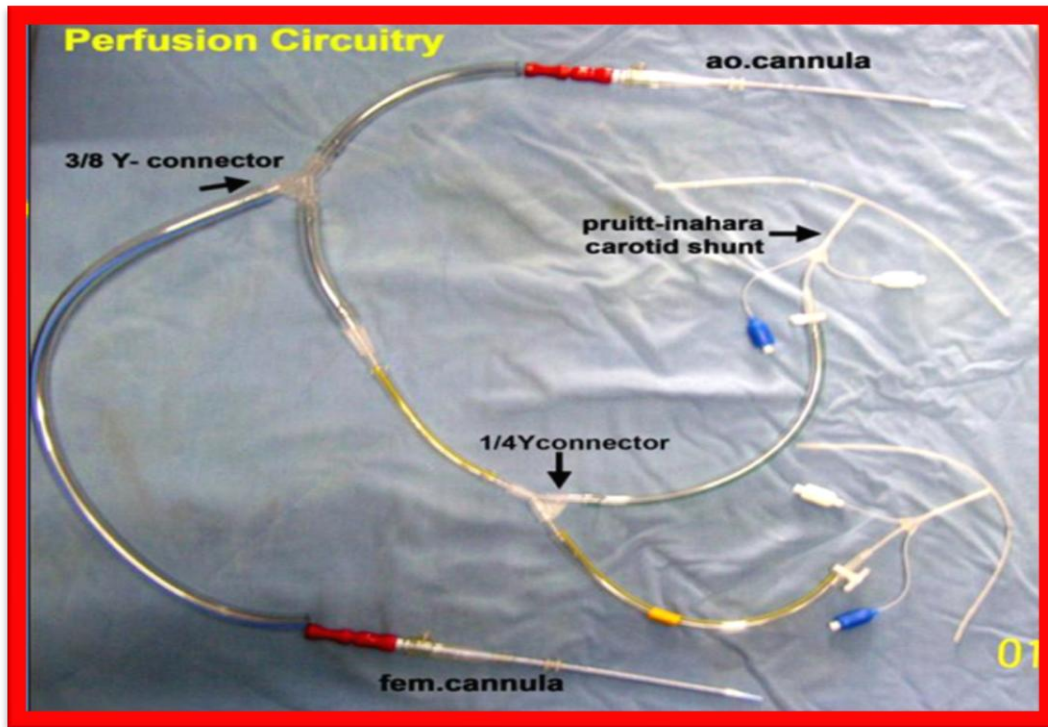


Figure-2- Showing Indigenous Aorto-femoral Circuitry made using tubes, aortic cannulas and Y connector used in cardiopulmonary bypass along with two Pruitt-Inahara shunts

After medial visceral rotation of all abdominal contents dissection of proximal, distal aortic aneurysm neck regions, identification and looping of left renal artery was done. Central tendinous portion of diaphragm was preserved for better respiratory recovery in postoperative period.

Heparinization was achieved before clamping by using 2-3 mg of unfractionated heparin to maintain activated clotting time (ACT) of >350 seconds as aortofemoral tubing circuitry was used for distal perfusion.

Aortic cannulation was done after cross clamping of proximal and distal aorta using the Medtronic 22/20/18 french aortic canula included in proximal portion of circuitry as per the size of individual aorta. In distal portion of circuitry 20 french Medtronic cannula was used to give retrograde distal perfusion into the graft attached to CFA. Purpose of using side graft to CFA was to avoid ipsilateral lower limb ischemia. Two Pruitt-Inahara carotid

catheters included in the aorto-femoral circuitry with use of Y connector were used to give perfusion to celiac, SMA, RRA and LRA.

Coated polyester graft was used in all patients, after proximal anastomosis if any critical intercostal artery identified in T8-L1 region were included in proximal bevelled anastomosis or reimplanted into the graft, Crawford's inclusion technique was used to implant celiac, superior mesenteric and right renal artery as a single Carrel mostly and left renal artery was implanted using the button of aortic wall, after completing the distal graft to aorta anastomosis to have proper assessment of lie so as to avoid any kinking of LRA. At completion of procedure 50% heparin reversal was given with Inj Protamine 1:1 ratio with UFH.

In patients with Stanford-B aortic dissection deep hypothermic circulatory arrest was used to repair by central aortic replacement just distal to left subclavian artery origin, using dacron graft with teflon felt reinforcement at proximal and distal anastomosis, was done after unification of the true and false lumens. Femoro-femoral CPB was used for hypothermia of 18-20° and main pulmonary artery cannulation was done in all patients for decompression of left atrium.

Interventional procedure:

TEVAR was done in the endovascular suite (DSA Lab) under fluoroscopic guidance. Procedure was done under GA or LA with awake sedation after securing venous access including a central venous line, arterial line for continuous blood pressure (BP) monitoring and urinary bladder catheterisation for assessment of urine output. Lumbar CSF drainage catheters were placed in selected patients who were at high-risk for spinal cord dysfunction due to coverage of long segment of DTA particularly T8-L1 region, history of prior

abdominal aortic repair or presence of occluded hypogastric arteries, and who present in hemodynamic shock all of which could jeopardized spinal cord collateral blood supply.

A standard surgical exposure of common femoral artery (CFA) is initially performed. CFA was punctured under vision and 6Fr vascular sheath placed. After advancing 0.035-inch hydrophilic guidewire to the proximal aorta beyond the pathological domain, a marker pigtail catheter is placed and aortogram obtained using pressure injector using diluted Visipaque (Low osmolarity and nonionized) contrast to delineate the anatomy and identify appropriate landmarks for executing the endorepair. Brachial access was taken occasionally, particularly in dissection cases to ensure true lumen access and for obtaining intra-operative injections.

After confirming the optimal landing sites, the hydrophilic guidewire is exchanged with superstiff Archer/Amplatz or Lunderquist guidewire. The stent-graft of appropriate size and length is taken and prepared by flushing through its ports. The stent-graft delivery system was introduced over the wire thorough the femoral artery by extending arteriotomy while the tapered tip (nose cone) engages the puncture site. The stent-graft was advanced with a controlled pushing motion, avoiding excessive force

An optimal proximal landing zone (PLZ) of 2-3cm and with a horizontal lie particularly in the arch of aorta is ensured and the stent-graft system is positioned appropriately. While the anaesthesiologist brings down the mean arterial pressure (MAP) to 70-80mmHg to avoid wind shock effect, the stent-graft is deployed in a controlled fashion using the standard deployment mechanisms of the delivery system as mentioned in the device instructions for use (IFU). After completion of deployment, ballooning of the proximal and distal ends (and overlapping segments if more than one stent-graft was used) is done to for complete radial sealing. A check angiogram is taken at end of procedure by reintroducing the pigtail catheter to ensure exclusion of aneurysm, false lumen entry/reentry tear or injury site,

rule out endoleaks and confirm normal flow in neighbouring aortic branch vessels. On completion, the catheter and guidewire is removed and femoral arteriotomy is closed in a standard manner using 5-0/6-0 polypropylene suture.

Surgical conduit placement

In case when the femoral artery is too small to accept the 22-24Fr sheath of the device or when intra-operative difficulty in negotiating the system was encountered, an additional 10mm polyester graft is attached to the common iliac artery or terminal aorta through an extra-peritoneal approach and brought out through femoral wound or separate stab wound to exterior. Graft access is done through a stab graftotomy rather than end of the graft for better haemostatic control. At end of the procedure, graft may be transected with a short stump or converted to ilio-femoral bypass graft in case the ilio-femoral arteries was significantly traumatize or iliac artery stenotic lesion was detected.

Hybrid procedures

For optimal proximal sealing in the transverse arch with adequate proximal landing zone length of 2-3 cm, prior elective 'debranching' and bypass of one or more brachio-cephalic vessels will be necessary preceding TEVAR. Totally cervical approach is employed with extra-anatomical carotid to carotid or carotid-subclavian bypass for Zone1 and Zone2 landing zones respectively, while Zone 0 deployment necessitates bypass inflow from ascending aorta through sternotomy approach by ascending aorto-bicarotid bypass. The surgical debranching procedure and TEVAR are usually staged by 1-2 days for initial physiological and wound stabilisation, unless there is an emergency indication or when a graft conduit has been required for access.

Carotid-carotid bypass: Bilateral common carotid arteries (CCA) are exposed by a vertical incision anterior to sternocleidomastoid muscles. After deepening the wound through platysma and deep fascia, the carotid sheath is incised and internal jugular vein retracted laterally. CCA is then dissected and looped for adequate distance above the level of superior belly of Omohyoid. A tunnel is created in anterior to the trachea within the subfascial plane. After heparinization, an 8mm polyester graft is anastomosed end-to-side to both CCAs sequentially, allowing 10-15 minute interval between each carotid clamp. Proximal end of left CCA is ligated doubly always.

Carotid-subclavian bypass: A transverse supraclavicular incision is placed and deepened through platysma and deep fascia. Clavicular head of sternomastoid is divided and inferior belly of omohyoid retracted. The carotid sheath is incised and CCA is then dissected and looped. Supraclavicular fat pad is taken off the clavicle and retracted away superiorly. Safeguarding the subclavian vein and brachial plexus, the 3rd part of LSCA is dissected and looped. After heparinisation, an 8mm polyester graft is anastomosed end-to-side from left CCA to LSA.

Aorto-bicarotid bypass: Standard median sternotomy is made. After partially thymic dissected and mobilisation of left innominate vein with looping, pericardium is opened over the proximal ascending aorta and aorta dissected on either side for a side-biting Satinsky/Leemole clamp. Both CCAs are exposed as described earlier. If bypass is planned for LSCA, the same may be dissected through separate incision in the supraclavicular area as described. After heparinization, side-biting clamp is placed as low on the ascending aorta as possible to keep the anastomosis maximum proximally so as to permit more proximal landing area for TEVAR. Either an inverted bifurcated 16/8mm or a 10mm polyester graft is attached to ascending aorta using 4-0 polypropylene with the distal anastomosis on either carotid using limbs of bifurcated graft or a separate 8mm graft to left CCA attached to the side of the

10mm graft anastomosed to right CCA. A separate 8mm graft can be attached to bypass LSA if indicated, The proximal parts of the 3 great vessels is then ligated/divided and suture closed within the chest.

Management of Left subclavian artery

In patients in whom Zone 0 to Zone 2 proximal landing is required, the subclavian artery is usually intentionally covered without prophylactic revascularisation, considering the abundant collaterals feeding the artery and the reversal of vertebral artery flow. On the contrary, in selected patients subclavian bypass is undertaken to maintain antegrade subclavian flow if there is high risk for posterior-circulation, spinal cord or upper limb ischemia. These include:

- a) Extensive coverage of DTA (>20cm)
- b) Previous abdominal aortic grafting
- c) Occluded hypogastric arteries
- d) Dominant left vertebral A or left vertebral A terminating into PICA without basilar A continuity
- e) Hypoplastic/absent right vertebral A
- f) Anomalous arch origin of left vertebral A
- g) Aberrant right subclavian A
- h) Patent LIMA bypass graft
- i) Functioning left upper limb AV fistula

Complete assessment of cerebral vasculature and posterior circulation in particular is important prior to considering intentional coverage of LSA lest disastrous complications could occur.

Data recording and analysis

Perioperative, all events were identified and recorded through review of patient records and the hospital's electronic medical records (EMR). Aortic disease related mortality included death from any cause within 30 days of the primary procedure or any secondary intervention. Subset analysis of mortality and complication rates were done in open and endovascularly managed cohorts. Categorical variables were investigated using Fisher's exact test and continuous variables using the Student *t* test. All statistical analysis was performed using MS Excel and SPSS 17.0, with *p* value of <0.05 considered significant.

Procedural details noted in open repair group:

- 1) Type of pathology(aneurysm/dissection)
- 2) Extent of aneurysm, Type-I/II/III/IV/V or DTAA with or without involvement of iliac arteries
- 3) Distal perfusion strategies use(AF Bypass)
- 4) Use of DHCA
- 5) Inclusion/Reimplantation of intercostal arteries
- 6) Use of passive moderate hypothermia 32-34° C
- 7) Use of pharmacological adjuncts-Methylprednisolone
- 8) Clamp timing

Outcomes analysed:

- 1) Cardiac morbidity
- 2) Respiratory morbidity
- 3) Renal dysfunction (transient/permanent)
- 4) Paraplegia/paraparesis
- 5) Visceral ischemia
- 6) 30-day mortality

Procedural details noted in TEVAR group were:

1. Nature of procedure endovascular, extent of pathology
2. Anaesthesia employed
3. Access vessel
4. Landing zone
5. Intentional coverage of LSCA and its revascularization
6. Type of hybrid procedure
7. Time interval between open and endovascular component
8. Use of CSF drainage

Outcomes Analysed:

1. Technical success
2. Subsystem complications
 - a. Cardiac
 - b. Respiratory
 - c. Renal dysfunction (transient/permanent)
 - d. Paraplegia/paraparesis
 - e. Visceral ischemia
3. Endoleaks
4. 30-day mortality

Any patient who has developed paraparesis/paraplegia, were assessed by neurologist and MR imaging was done to look for cause.

Definitions

Technical success: relates to periprocedural events that occur from the initiation of the procedure and extend through the first 24-hour postoperative period. Primary technical

success is defined as the successful introduction and deployment of the device in the absence of surgical conversion or procedural mortality, type I or III endoleaks, or graft limb obstruction. A technical success thus implies the following qualifying details:

1. Successful access to the arterial system using a remote site (ie, the femoral, external iliac, common iliac, or brachiocephalic arteries with or without use of a temporary or permanent prosthetic conduit to access these arteries
2. Successful deployment of the endograft with secure proximal and distal fixation zones
3. Absence of either a type I or III endoleak
4. Patent endograft without significant twist
5. Kinks, or obstruction (>30% luminal stenosis or a pressure gradient >10 mm Hg) by intraoperative measurements

Initial/perioperative or 30-day clinical success encompasses 30-day data.

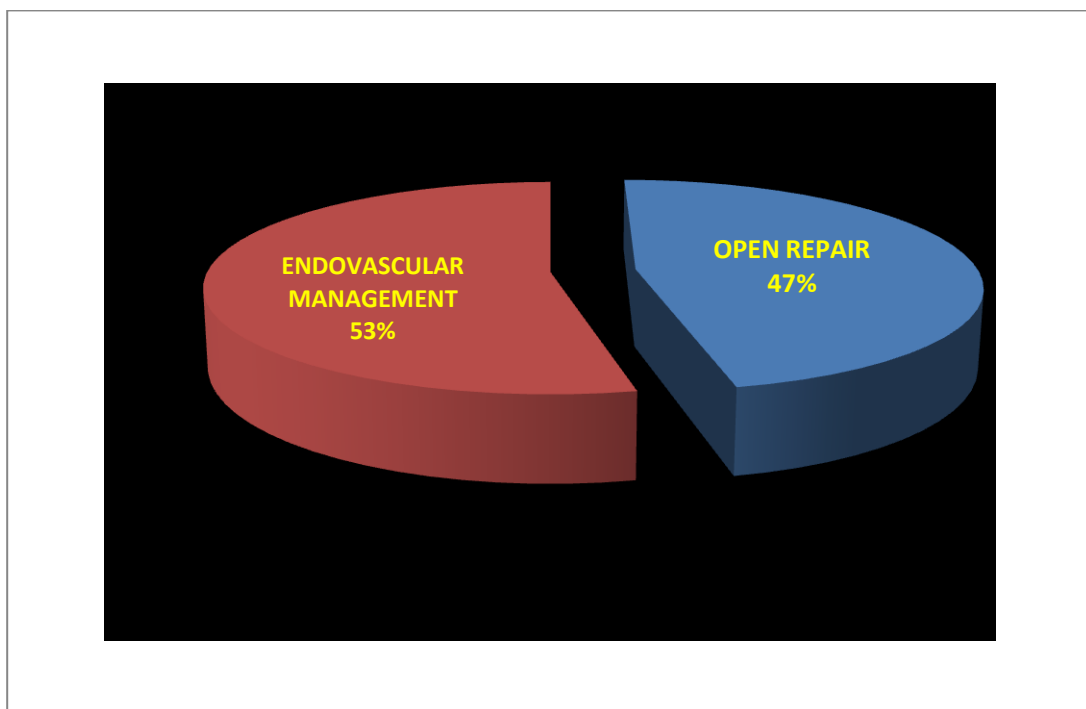
Endoleaks: is defined by the persistence of blood flow outside the lumen of the endoluminal graft but within the aneurysm sac, as determined by an imaging study.

Classification of Endoleaks:

Type	Cause of perigraft flow
I	A: Inadequate seal at proximal end of endograft B: Inadequate seal at distal end of endograft
II	Back-flow from branch vessels without attachment site connection
III	A: Modular stentgraft components disconnection B: Fabric disruption
IV	Flow from porous fabric (<30 days of graft placement)
V (Endotension)	Aneurysm expansion without detectable flow

Results

During the study period of five years, 116 patients underwent treatment of thoracic aortic pathologies, out of which 54 underwent open repair and 62 patients were managed by the state-of-the-art standard TEVAR or hybrid TEVAR.



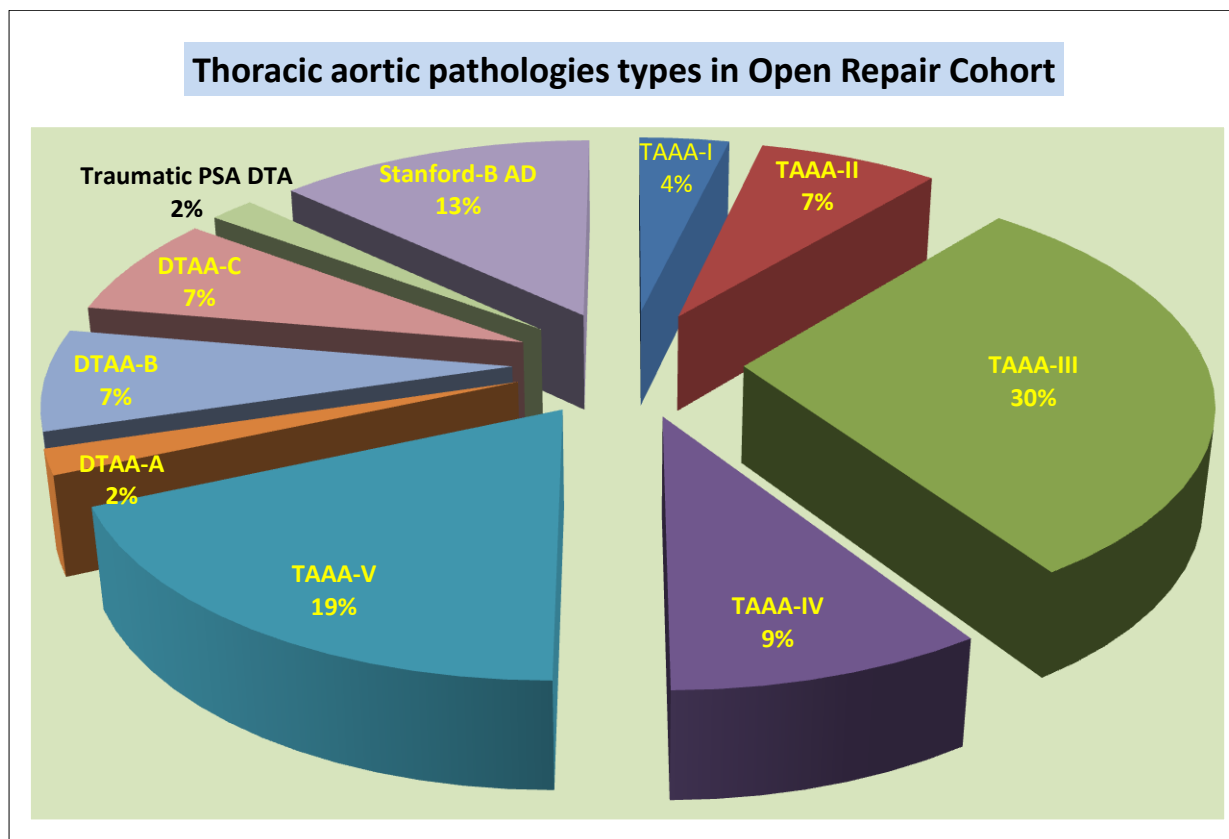
Graph 1 : Number of patients managed with open and endovascular strategy.

Demographic and clinical details of the patients managed by open repair of thoracic and thoracoabdominal aortic aneurysms, aortic dissection and distal aortic arch and descending thoracic aortic aneurysm are summarised in table 1.

Demographic details of patients managed by open repair of Thoracic aortic pathologies	
Age	54(20-78)
Male:Female	14.8:1(46:8)
HTN	59%(31)
DM	18.8%(10)
CAD	14.8%(8)
PAD	9.2%(5)
Renal dysfunction	1.85%(1)
COPD	9.2%(5)
Smoking	55.5%(30)
Dyslipidemia	37.03%(20)

Table 1: Demographics of open repair cohort. CAD = coronary artery disease, COPD = chronic obstructive pulmonary disease, HTN=hypertension, DM=Diabetes mellitus, PAD = Peripheral artery disease.

All patients in open cohort underwent elective surgeries, no emergency repair was done in open group. Different pathologies managed in open group includes thoracoabdominal aortic aneurysm 68%(37), descending thoracic aortic aneurysm 16.65%(9), Stanford-B chronic aortic dissection cases 13%(7) and 1.85%(1) case of traumatic pseudoaneurysm in proximal DTA. Distribution of further subtypes of various aneurysms under TAAA and DTAA are shown in graph 2.



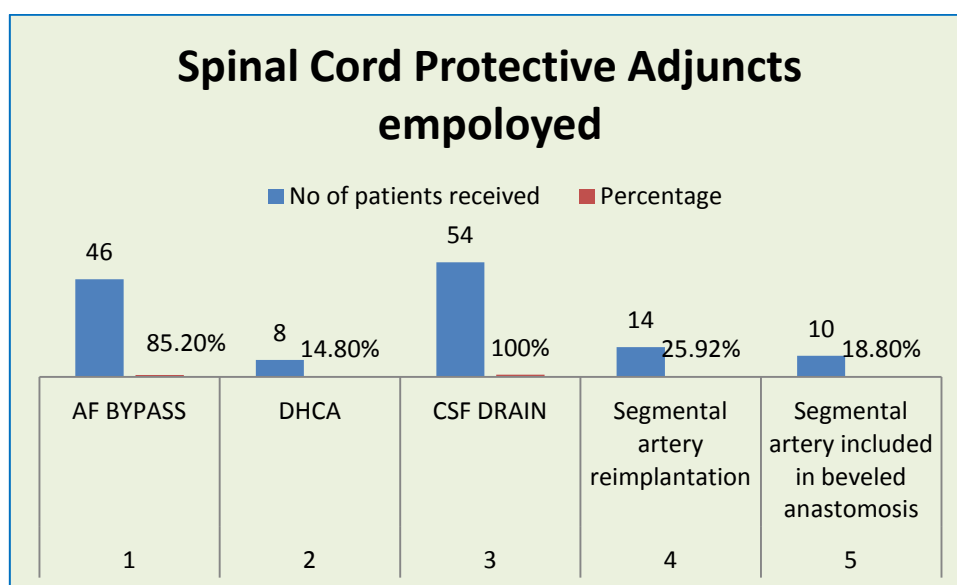
Graph 2: Showing distribution of various types of aneurysms and aortic dissection cases managed by open repair

Procedural details:

Total 54 patients underwent repair of thoracic aortic and thoracoabdominal aortic pathologies. All patients were repaired by the protocol as described in material section. Distal aortic perfusion strategy, an indigenous aorto-femoral passive shunting technique was employed in 85% (46) of the patients for maintaining perfusion to hypogastric, lower limb and retrograde flow to viscerorenal arteries. All patients with Stanford B aortic dissection, where proximal clamping was difficult and risk of bleeding was high due to disturbed hemodynamic flow in true and false lumen were operated under the deep hypothermic circulatory arrest 15% (8). For maintaining the blood flow of the spinal cord collateral

network cerebrospinal fluid drainage is standard for all patients managed by open repair at our institute, it was used in all 54 patients (100%).

Inclusion of intercostal arteries in T8-L1 spinal cord level, were achieved in 44.72% of patients by reimplantation in 25.90%(14) and by inclusion in bevelled anastomosis in 18.80%(10)(Graph-3). In 2 patients SSEP/MEP were used while undergoing repair of TAAA, but its use was not found to be helpful.



Graph-3: showing the percentage wise use of different strategies in open repair group

Paraplegia developed in 5.5% (3) of cases. Two afflicted patients underwent repair under aortofemoral bypass and one under DHCA. CSF drainage was used in all the three cases. One patient had extensive TAAA-II aneurysm, undergone repair under DHCA. Out of 3 patients, two patient expired in perioperative period and one patient expired after two months following infected pancreatic necrosis. None of the patients had any inclusion of intercostal arteries, as one patient had very small segmental artery and two did not have any back bleeding segmental arteries in T8-L1 region. All procedural details of the patients affected by paraplegia are summarised in table-2.

Sr. No:	Patient's affected by paraplegia	Managed by
1	Type-II TAAA	DHCA,CSF Drainage, No larger segmental artery for inclusion
2	Type-III TAAA	AF bypass, CSF Drainage, Very small segmental artery not included
3	Type-V TAAA	AF bypass, CSF Drainage, No segmental artery found for inclusion

Table-2: Procedural details of the patients afflicted by paraplegia.

Out of 54 patients, the 30 day mortality was 16.6%(9), 3 patients were expired due to postoperative bleeding following disseminated intravascular coagulation, 4 patients had multiorgan dysfunction syndrome, one patient had ARDS and one patient suffered pancreatitis along with gall bladder perforation and succumbed following sepsis.

Various morbidities in perioperative 30 day period are summarised in table-3.

Perioperative 30 day Morbidities and Mortality		
1	Renal Failure	-
a	Temporary(No dialysis)	22.2%(12)
b	Dialysis temporary	1.87%(1)
2	Respiratory Failure	7.4%(4)
3	Retroperitoneal Collection	1.8%(1)
4	Postoperative stroke	1.85(1)
5	Paraplegia	5.5%(3)
6	Mortality	16.6%(9)

Table 3: Perioperative 30 day morbidities in patients managed by open repair

24%(13) of the patients had temporary renal dysfunction manifested by increase in 0.5mg/dl as compared to preoperative value following the surgery. Only one patient required few dialysis till recovery of renal function. None of the patient discharged to dialysis high dependency units for permanent dialysis. Respiratory complications mainly involved bronchospasm, atelectasis or pneumonia occasionally requiring prolonged ventilation (>48 hrs) or re-intubation occurred in 7.4%(4) of the patients which was managed in 3.7%(2) of cases by tracheostomy. One patient (1.87%) developed retroperitoneal haematoma which was managed by drainage. Perioperative stroke occurred in one patient(1.87%) which improved to normal in the follow up period.

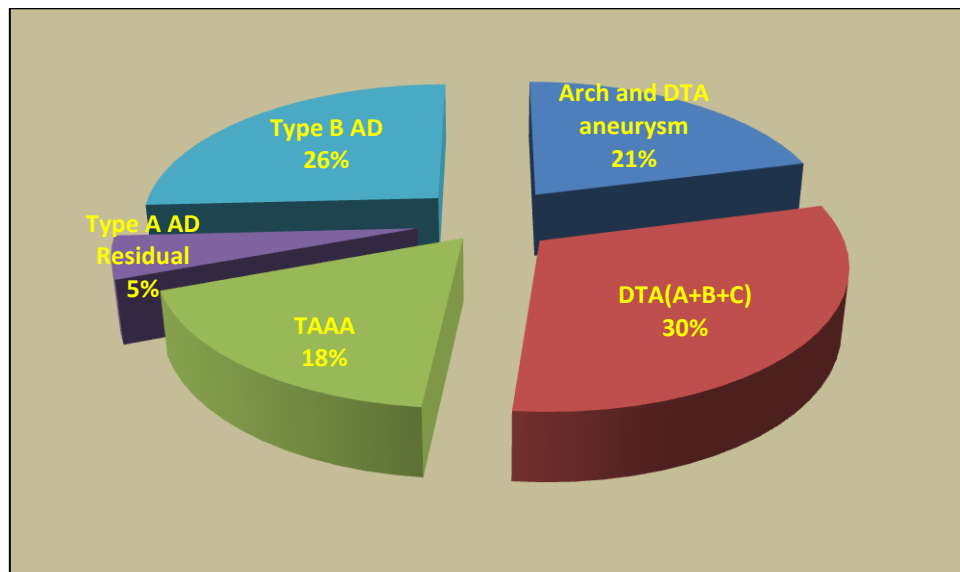
The demographic profile of the patients which were managed by TEVAR and hybrid TEVAR is summarised in table 4.

Demographics and Clinical Details		
1	No. of patients	62
2	Age in yrs (mean)	59.1(20-87)
3	Mean aortic diameter (in mm)	58.5
4	Male : Female	56:6(9.6:1)
5	Smoking	45.1%(28)
6	Hypertension	93.5%(58)
7	Diabetes mellitus	9.6%(6)
8	Dyslipidemia	12.9%(8)
9	CAD	11.2%(7)
10	COPD	9.6%(6)
11	Renal Dysfunction	12.90(8)
12	CVD	3.2(2)
13	PAD	8.0%(5)
14	Previous aortic surgery	6.4%(4)
15	Hemodynamic instability at presentation	8.0%(5)

Table 4: Demographics of study population managed by Endovascular strategy. CAD = coronary artery disease, COPD = chronic obstructive pulmonary disease, CVD = cerebrovascular disease, PAD = peripheral artery disease.

Pathologies treated by TEVAR and hybrid TEVAR included 30% of descending thoracic aortic aneurysms, 18% of TAAA (all Hazim Safi's type V), 21% of patients had extensive aneurysmal involvement of distal arch and descending thoracic aorta and remaining

31% of the patients had aortic dissection with Stanford-B chronic type in 26% and residual Stanford A dissection following Bentall DeBono procedure in 5%(3) of patients(Graph 4).



Graph 4: Various pathologies of thoracic aorta managed by TEVAR and hybrid TEVAR.

Out of 62 patients, 32%(20) patients were managed on emergency basis due to rupture/leak and 67.7%(42) patients were managed on elective basis.

Procedural details:

The common femoral artery (CFA) was utilised as access vessel for delivery of the endoprosthesis in 58 (93.5%) patients, while 4 (6.4%) cases required additional conduit placement to common iliac artery (CIA) or terminal aorta due to small calibre of CFA/Iliac arteries for delivery of device. The femoral limb of a prior aorto-femoral bypass graft was using in 2 cases. 1 patient had a CIA stenosis that had to be stented using a self-expanding bare metal stent prior to passage of the device.

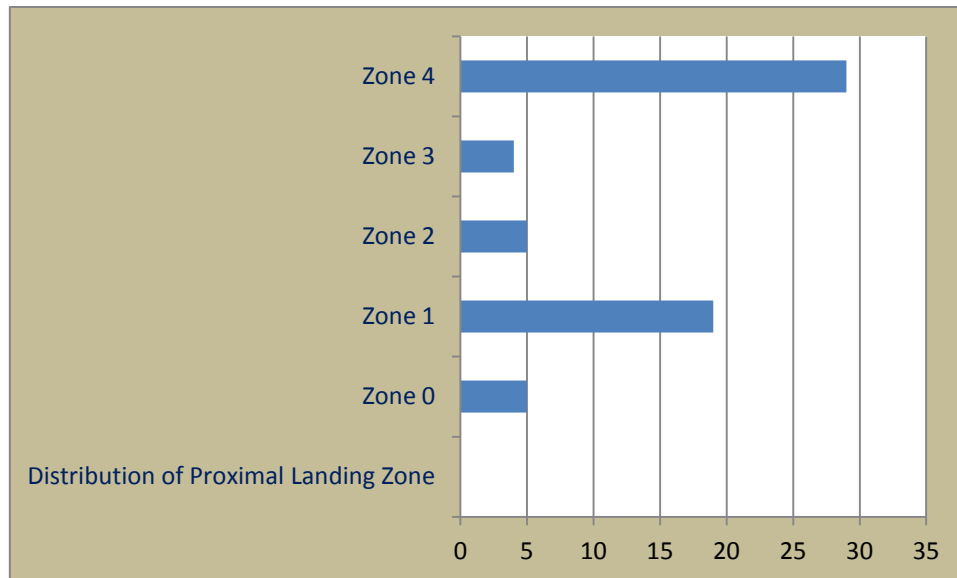
26 (42%) cases were performed under local anaesthesia with awake sedation, predominantly in the elective group; while GA was employed in 36 (58%) cases for various reasons of hemodynamic instability, obesity, patient anxiety or when a conduit placement or synchronous hybrid repair was required. Lumbar subarachnoid catheter was placed for CSF drainage in 16(25.8%) cases that posed high risk for spinal cord ischemia.

Out of the 75 aortic stent-grafts used, majority (67) were Valiant Thoracic endoprosthesis with Xcelerant or Captivia delivery system (Medtronic Inc, Minneapolis, MN, USA), Zenith TX2 TAA endoprosthesis (Cook Medical Inc., Bloomington, IN, USA) was used in 6 while 2 cases were performed using the TAG endoprosthesis (W.L Gore, Flagstaff, AZ, USA). 13 cases required the deployment of 2 stent-grafts on account of the sheer length of the aneurysm or to tackle endoleak. Graft diameters employed ranged from 24 to 46mm (median; 35mm). Patients managed by standard TEVAR were 58% and hybrid TEVAR was performed in 42% of patients for adequate sealing zone in zone 0, and zone I. Table 5 summarises the details of the procedures executed in endovascular cohort.

Distribution of Standard TEVAR and Hybrid TEVAR			
Sr.No	TEVAR type	No	Percentage
1	Standard TEVAR	36	58.00%
2	Hybrid TEVAR	26	42.00%
a	Hemiarch Debranching (Carotid to carotid bypass and Ascending Ao to LCCA bypass	19	30.64%
b	Pan Debranching	5	8.00%
c	Visceral debranching/AF bypass	2	3.22%

Table 5: Standard TEVAR is managed with TEVAR, Hemiarch Debranching is either carotid to carotid bypass or ascending aorta to left carotid bypass, Pan debranching is Ascending aorta to bicarotid with SCA bypass. One patient required Ilio-mesenteric bypass for safe distal landing over SMA.

PLZ in which deployment was executed involved Zone 0 in 5, Zone 1 in 19, Zone 2 in 5, Zone 3 in 4 and Zone 4 in 29 patients. Graph 5 depicting distribution of proximal landing zones in patients managed by TEVAR and hybrid TEVAR.



Graph 5: Showing the different landing zones required for proximal sealing zone. Horizontal axis depicting the number of patients with different landing zones out of 62.

The left subclavian artery was intentionally covered in 29 (46.77%) patients while prophylactic bypass on selective indications were given in 6(9.6%) patients. No neurological event pertaining to left SCA coverage or upper limb ischemic sequelae noted in any of the former patients.

Perioperative outcomes

Technical success was achieved in 60 patients (96.7%). Overall 30-day mortality was 6.4% (n=4) (Table 6), Mortality was marginally higher in the hybrid group was 7.69% (n=2) compared to 5.5% (n=2) in TEVAR alone group. On comparing the elective and emergent

treatment group, mortality was 4.7% (n=2) in elective setting while it was 10% (n=2) among patients treated in emergency.

Respiratory failure + Paraplegia	1
Acute on chronic Renal failure	1
Visceral Malperfusion	1
Pancreatitis, Gall bladder and colonic perforation(Trash)	1

Table 6: Summarises the causes of mortality in each patient in endovascularly managed group

Early major post-operative complications are listed in Table 7. Complication rates were higher in the patients treated with hybrid repair than those requiring only TEVAR, and were also higher in emergent group in comparison with elective group. Most commonly encountered were respiratory and renal complications.

Perioperative Morbidity and Mortality			
Sr. NO	Perioperative Morbidity and Mortality	Standard TEVAR	Hybrid TEVAR
1	Mortality	5.5%(2)	7.6%(2)
2	Neurological complications	-	-
3	Stroke	0	0
4	Paraplegia	0	3.8%(1)
5	Cardiac complications	2.7%(1)	3.8%(1)
6	Respiratory complications	8.3%(3)	30.76%(8)
7	Renal dysfunction	-	-
a	Transient dysfunction	19.44%(8)	23.07%(6)
b	Renal failure	2.7%(1)	3.8(1)
8	Visceral ischemia	0	3.8%(1)
9	Venous thromboembolism	0	0
10	Wound/access related complications	11.11%(4)	19.23%(5)
11	Endoleaks (I or III)	5.55%(2)	3.8%(1)

Table 7.30-day postoperative outcomes comparing TEVAR alone and hybrid groups.

Respiratory complications mainly involved bronchospasm, atelectasis or pneumonia occasionally requiring prolonged ventilation (>48 hrs) or re-intubation. Renal complications were predominantly transient rise in S. creatinine > 0.5mg% largely related to contrast-induced nephropathy (CIN) that subsided with conservative management within a week or two. Wound complications comprised of wound infection in 5 patients, neck hematoma in 2

patients following subclavian bypass and groin lymphorrhoea in 4 patients in hybrid and standard TEVAR group respectively.

One patient in TEVAR cohort (1.61%), developed dense paraplegia following the hybrid TEVAR repair for the distal arch and type A descending thoracic aortic aneurysm. This patient underwent ascending aorta to bicarotid and left subclavian artery bypass followed by TEVAR. Debranching was done with coated polyester prosthesis of size 14X7mm and long aneurysm mandated deployment of two Medtronic Valiant stentgrafts (36mmx224mm and 42mmx224mm). Patient developed immediate dense paraplegia, although CSF drainage was used along with optimization of mean arterial pressure of >90mmHg. Patient gradually developed MODS and expired.

Total Number of patients Suffered Paraplegia in TEVAR group		
1	TEVAR group	1.6%(1)
2	Open Repair group	5.5%(3)
Total		3.44%(4)

Table 8: Total number of patients affected by paraplegia

Including both open repair and TEVAR cohort of thoracic aortic pathologies, 3.44%(4) patients developed paraplegia. In TEVAR group 1.6%(1) and in open repair group 5.5%(3) patients developed paraplegia(Tab:-). Low paraplegia rate in TEVAR patients is published in literature. But in present series there are more TAAA aneurysms(68%) in open repair cohort compared to TEVAR group which had >50% DTAA and >25% aortic dissection cases which mandated lesser coverage of thoracoabdominal aorta and so sacrifice of segmental arteries were less.

Results in this retrospective study includes the perioperative data till discharge of the patients.

Discussion

Over the course of time with improvements in surgical techniques and spinal protective adjuncts along with intraoperative anaesthesia and postoperative critical care management all together has significantly brought down the incidence of spinal cord dysfunction and mortality associated with surgical management of thoracic aortic pathologies. TEVAR has revolutionized the management of thoracic aortic diseases. Advantages of a minimally invasive endovascular approach are avoiding of thoracotomy, aortic cross-clamping, reduced procedure times, and decreased blood loss. TEVAR is emerging as the preferred treatment for patients with thoracic aortic pathologies both in the elective and emergent setting, although there is currently a scarcity of Level I evidence that an endovascular approach improves survival compared with traditional open surgery. TEVAR has taken over the surgery as main modality to manage descending thoracic aortic aneurysm and Stanford-B aortic dissection but surgery is still the treatment of choice for thoracoabdominal aortic aneurysms.

In this study we have analysed the results of spinal cord dysfunction following management of thoracic aortic pathologies by open and endovascular means with use of adjuncts like distal perfusion by aortofemoral bypass, CSF drainage and inclusion of intercostal artery techniques in open repair and selective LSCA revascularization and CSF drainage where ever indication of high risk existed(8).

Although it is difficult to find out how much each adjunct contributed individually to reduce the incidence of this devastating complication.

Incidence has definitely decreased (5.5% in open group and 1.6% in TEVAR group) with use of these host of strategies. In RCT by Coselli et al, patients with extent I and II TAAA, the distal perfusion by left hear bypass had a statistically significant lower incidence of paraplegia or paraparesis (17 of 375, 4.5%) compared with the non-LHB group (29 of 259,

11.2%) (49). In open repair group, 85 % of patients underwent repair under aortofemoral bypass. Results in this present study has shown comparable results in lowering the incidence of paraplegia/paraparesis (5.5%).

Initial RCT by Stanley Crawford has failed to show any benefit of CSF drainage, in that study CSFD was limited to only intraoperative period with CSF drainage limited to 50ml only, but further well conducted RCT by Coselli et al has shown incidence of paraplegia in CSFD 2.7% and patients without CSFD 12.2%, has confirmed the significant benefit achieved by use of CSFD for maintaining the spinal cord perfusion(35). In present study CSFD was employed in 100% of patients with paraplegia incidence of 5.5%(3/54).

Maintaining spinal cord blood flow by reattachment of intercostal arteries has difference of opinions by data published by Charles Acher et al which has shown quick oversewing of intercostal arteries with use of adjuncts like CSFD, naloxone with systemic moderate hypothermia can reduce the paraplegia risk to near 3%(18) while Safi H J et has reported rate of neurological deficits was 50% in the ligation group versus 12.9% in the reimplantation group and 9.9% in the group who had pre-existing occlusion(28). Our strategy is to include the any significant intercostal artery in T8-L1 area if any back bleed is there, by adopting this strategy we have used reimplantation/bevelled inclusion of intercostal arteries in 44.44% of patients(24/54). In this series none of the patients in which inclusion of intercostal/reimplantation was done has suffered the paraplegia, and so this confirms the definitive place of reimplantation of intercostal arteries as reported by Hazim Safi et al group. In open repair group overall incidence of paraplegia is 5.5% with strategic use of host of adjuncts, which is well comparable with the published literature.

In endovascular group, with use of selective CSFD and LSCA revascularization the incidence is 1.4%(1/62). In this series, intentional blockade of left subclavian artery was performed in 28 patients (45.1%), without prophylactic bypass. A few studies report that

intentional coverage is not associated with additional morbidity (50-52), whereas other studies report a higher incidence of postoperative arm ischemia and posterior circulation strokes (53-54). Routine revascularisation is not without risk. Wound hematomas, injuries to lymphatic, vascular and nervous structures are potential complications seen in around 5% cases(55). Although the level of evidence to support either practice is low, data from this study indicates that risk of vertebra-basilar insufficiency or arm ischemia is low in most patients. Yet it is of paramount importance to assess the posterior circulation and branching pattern of arch vessels prior to the procedure and to identify particular situations that impose a threat for development of these devastating complications and provide prophylactic bypass to retain antegrade subclavian-vertebral flow in this subset of patients as was done in 6 cases in this study.

We employed selective LSCA bypass strategy in high risk patients(8). Spinal cord dysfunction of 1.4% in this series, with use of this selective revascularization has resulted in excellent results considering spinal cord dysfunction.

CSF drainage use for prevention of paraplegia/paraparesis in patients treated with endovascular strategy has evolved from surgical experience of management of TAAA/TAA. As there is no consensus due to lack of level I evidence when it comes to use of CSF drainage during TEVAR. Some would use it always, while some employ it selectively in cases where there is an evident risk from paraplegia development. In this selective group, some would use CSF drainage in strictly anatomically appropriate situations (we have similar strategy), while others would employ this only after a patient displays features of spinal cord dysfunction (8). Wong CS et al in a systematic review of spinal cord dysfunction and CSF drainage after thoracic aortic endografting over all, SC insufficiency affected 3.89%. Series with routine prophylactic CSF drain placement or no drain placement reported pooled SC insufficiency rates of 3.2% and 3.47%, respectively. The SC insufficiency rate from 24 series stating that

prophylactic drainage was used selectively was 5.6%(56). In present series CSFD was employed in 25.8%(16) of patients, and this strategic use has resulted in SCI rate of 1.4%.

Currently, data is insufficient to allow meaningful evaluation of the risks v/s the benefits of prophylactic CSFD in TEVAR, although results of this study supports the selective use of CSFD.

Mehmedagic I et al has reported complications of CSF drainage in protection of spinal cord function during management of thoracoabdominal aortic pathologies like Meningitis, epidural, and subdural hematoma and needle-mediated paresis occurred after CSF drainage apart from non functioning of CSF drain(57). In this present study although hemorrhagic aspirate has come in 3 patients while employing CSF drain, but none of the patient had any complication.

Advent of newer technologies capable of delivering total endovascular solutions like fenestrated, and branched endografts for thoracic/thoracoabdominal aortic diseases, complimented by better understanding of the dynamics of thoracic aorta with resultant improvement in device fabrication, the scope of TEVAR and hybrid repair is likely to expand further with added refinements in the therapy of thoracic aortic pathologies providing results with lesser morbidity and better long-term survival

Conclusion

Spinal cord ischemia following Open or Endovascular management of thoracic aortic pathologies is a rare but unpredictable catastrophe. Appropriate use of host of strategies particularly distal aortic perfusion, CSF drainage and reimplantation of significant intercostal arteries in critical zone of T8-L1 can reduce incidence of spinal cord ischemia significantly but differential use of these strategies across the globe is testimony that none of the modality is 100% effective.

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CLASSICAL CASES

Figure 1: Case of Type III equivalent TAAA due to Takayasu's Arteritis, with single functioning left kidney drained by ovarian veins and severe infra renal aortic stenosis

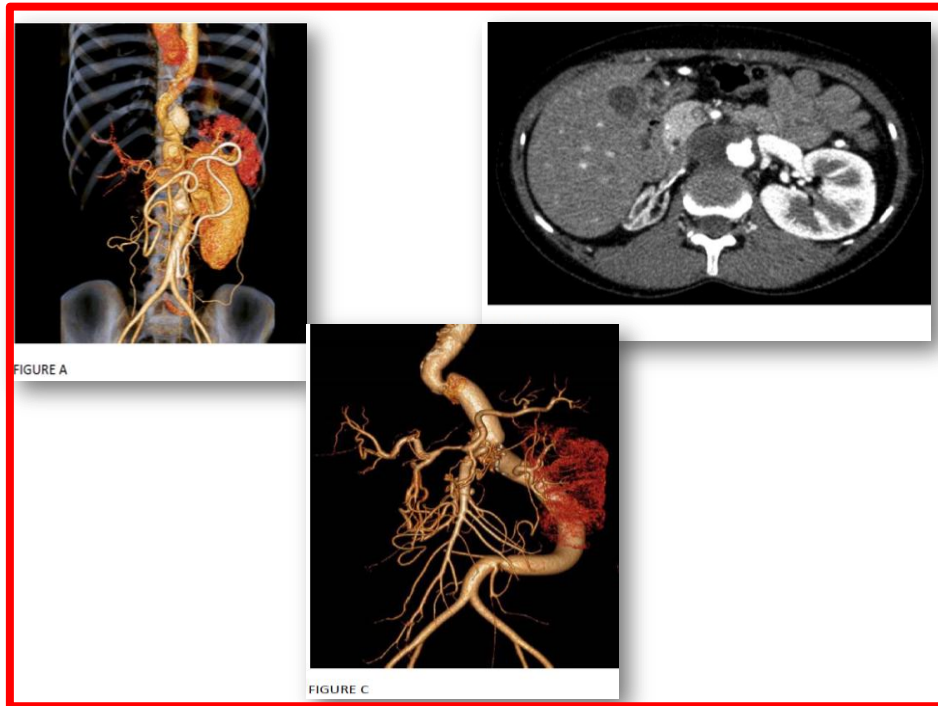
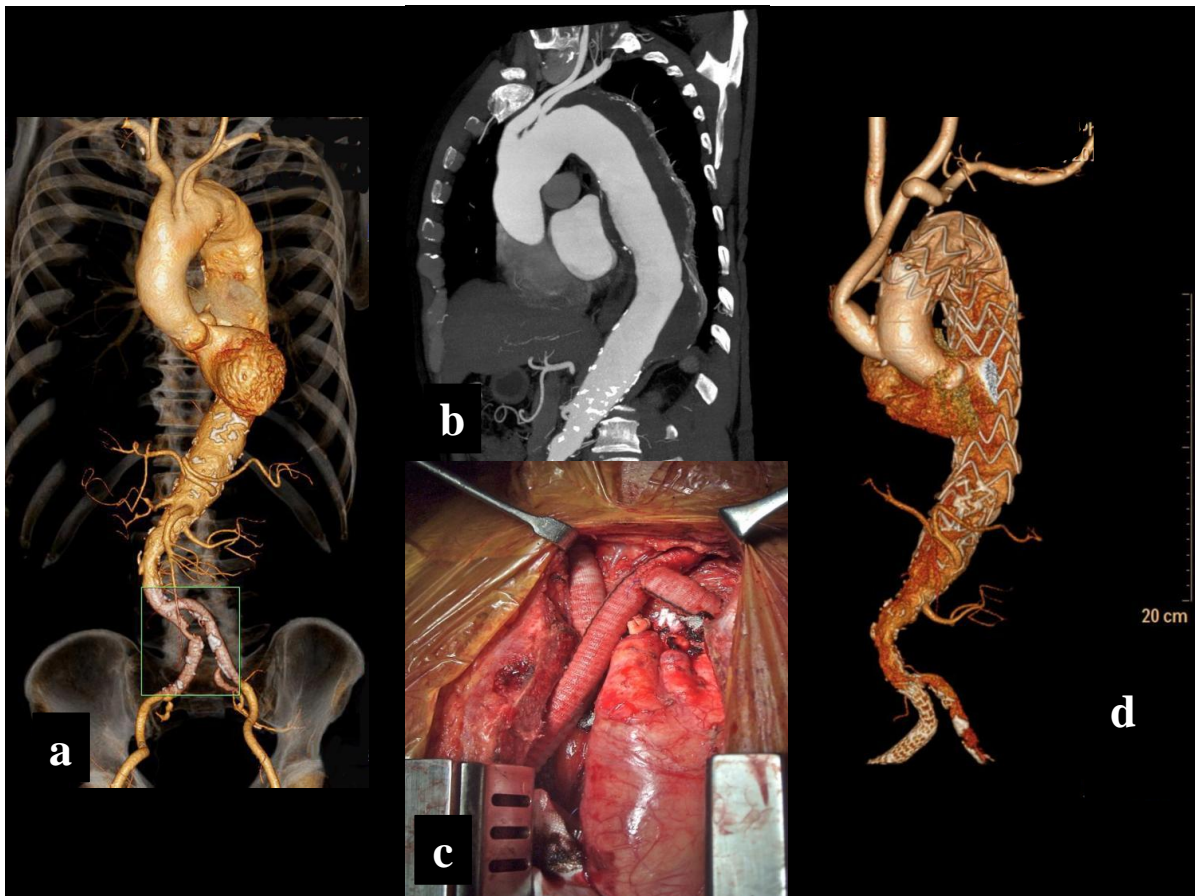


Figure A: Preoperative reconstructed CT angiogram showing multiple saccular aneurysms in the Thoracoabdominal aorta; hypertrophied left Kidney with left renal vein draining into ovarian vein. Near total occlusion of infra renal aorta and its distal reformation via Arc of Riolan forming distal run-off into aorta through retrograde flow in inferior mesenteric artery.

Figure B: Preoperative axial view of contrast CT abdomen showing solitary functioning kidney with compensatory hypertrophy and left renal vein draining into ovarian vein ; grossly shrunken and atrophic right kidney and large amount of layered thrombus in the aortic aneurysm.

Figure C: Postoperative CT reconstructed image showing patent graft and reimplanted Celiac , Superior Mesenteric and Left Renal Arteries. Normalized inferior mesenteric artery antegrade flow with disappearance of Arc of Riolan.

Figure 2: Hybrid repair for extensive aneurysm from distal ascending aorta upto hiatus

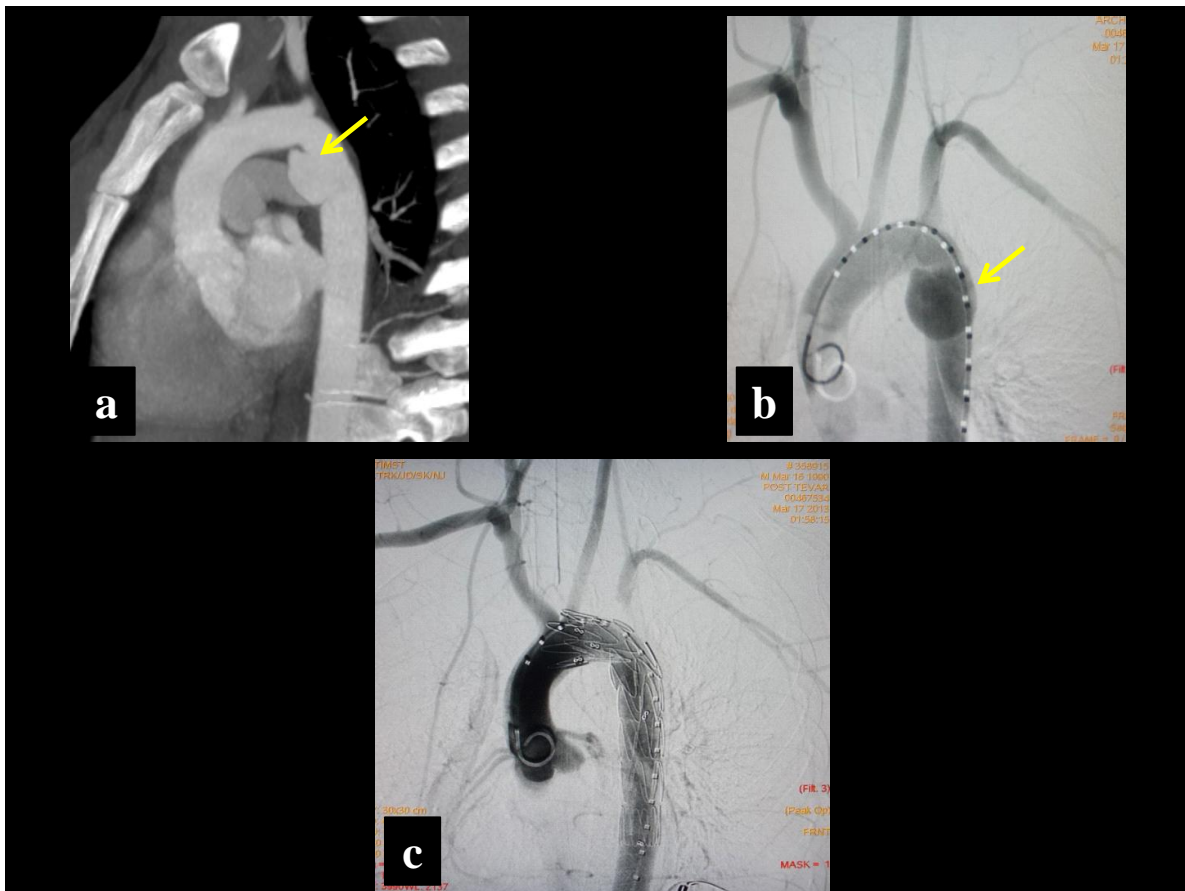


A: CT-angiogram, volume rendered 3-dimensional image, showing the extent of the aneurysm from distal ascending aorta upto supraceriac thoracic aorta

B: CT-angiogram, multiplanar reconstructed image, showing large aneurysm of maximum diameter of 8.5cm with thrombus

C: Intra-operative photograph showing the re-routing of all supra-aortic trunks taking inflow from proximal ascending aorta, along with the debranching (ligation) of the native arteries

D: CT-angiogram, volume-rendered 3-dimensional image, 6 months after endorepair using 2 Medtronic Valiant thoracic stent-grafts (44x210mm and 46x210mm), showing patent bypass grafts to both carotids and left subclavian artery with good stent-graft apposition and complete exclusion of aneurysm. Right common iliac artery had to be stented due to 60% stenosis to permit passage of device.

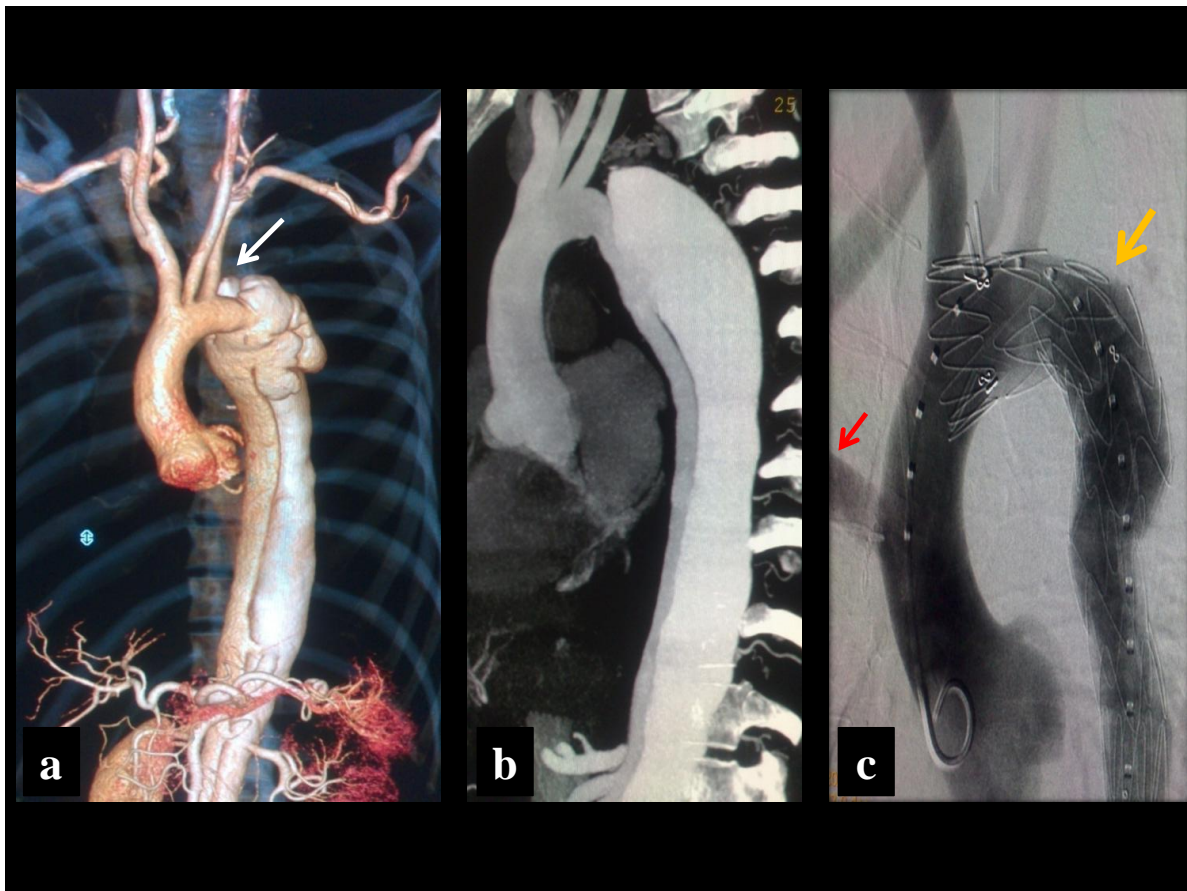
Figure 3: TEVAR for Traumatic aortic injury in a 23 year old poly trauma patient

A: CT-angiogram, multiplanar reconstructed image , revealing a pseudoaneurysm at the aortic isthmus in a patient who recently sustained a major road-traffic accident

B: Digital subtraction angiogram with aortic injection through marker pigtail catheter prior to stent graft deployment confirming the traumatic aortic lesion

C: Digital subtraction angiogram at the completion of deployment of 24x112mm Medtronic Valiant thoracic aortic stent-graft into Zone 2 showing complete exclusion of pseudoaneurysm with retrograde left subclavian artery flow

Figure 4: Hybrid repair in a case of chronic type B aortic dissection

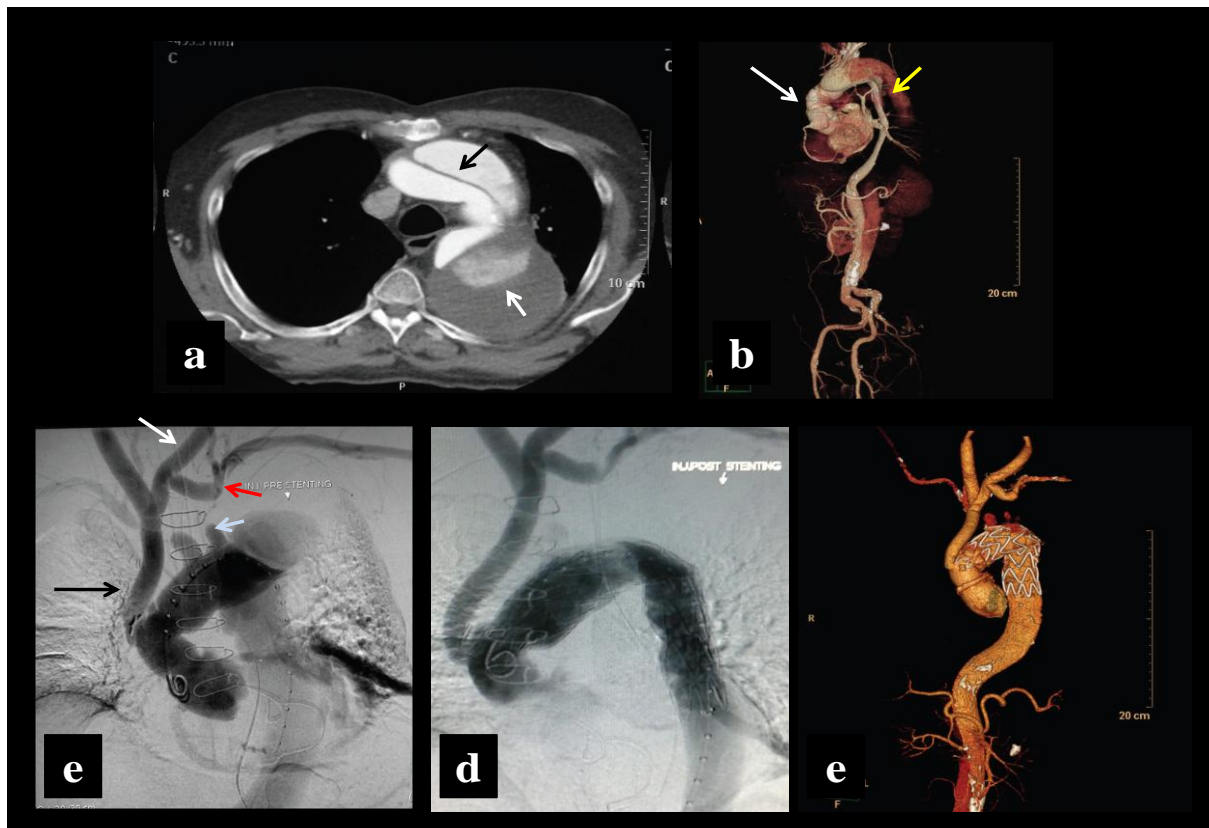


A: CT-angiogram, volume rendered 3-dimensional image, showing Stanford B aortic dissection arising just distal to left subclavian artery (white arrow)

B: CT-angiogram, multiplanar reconstructed image, large entry tear in post-subclavian descending thoracic aorta with enlarged flow lumen and compressed true lumen

C: Digital subtraction angiogram taken at the completion of staged repair (left carotid debranching with ascending aorto-left carotid bypass (red arrow) and endorepair with Medtronic Valiant thoracic 24 x 152mm stent-graft showing non-opacification of false lumen and opened up true lumen)

Figure 5: Staged Hybrid repair for progressive dissection with aneurysmal degeneration 4 years following supra coronary replacement of ascending aorta for Type A dissection



A: Preoperative axial contrast CT chest showing intimomedial flap in the aortic arch (black arrow) and partially thrombosed aneurysmal false lumen (white arrow).

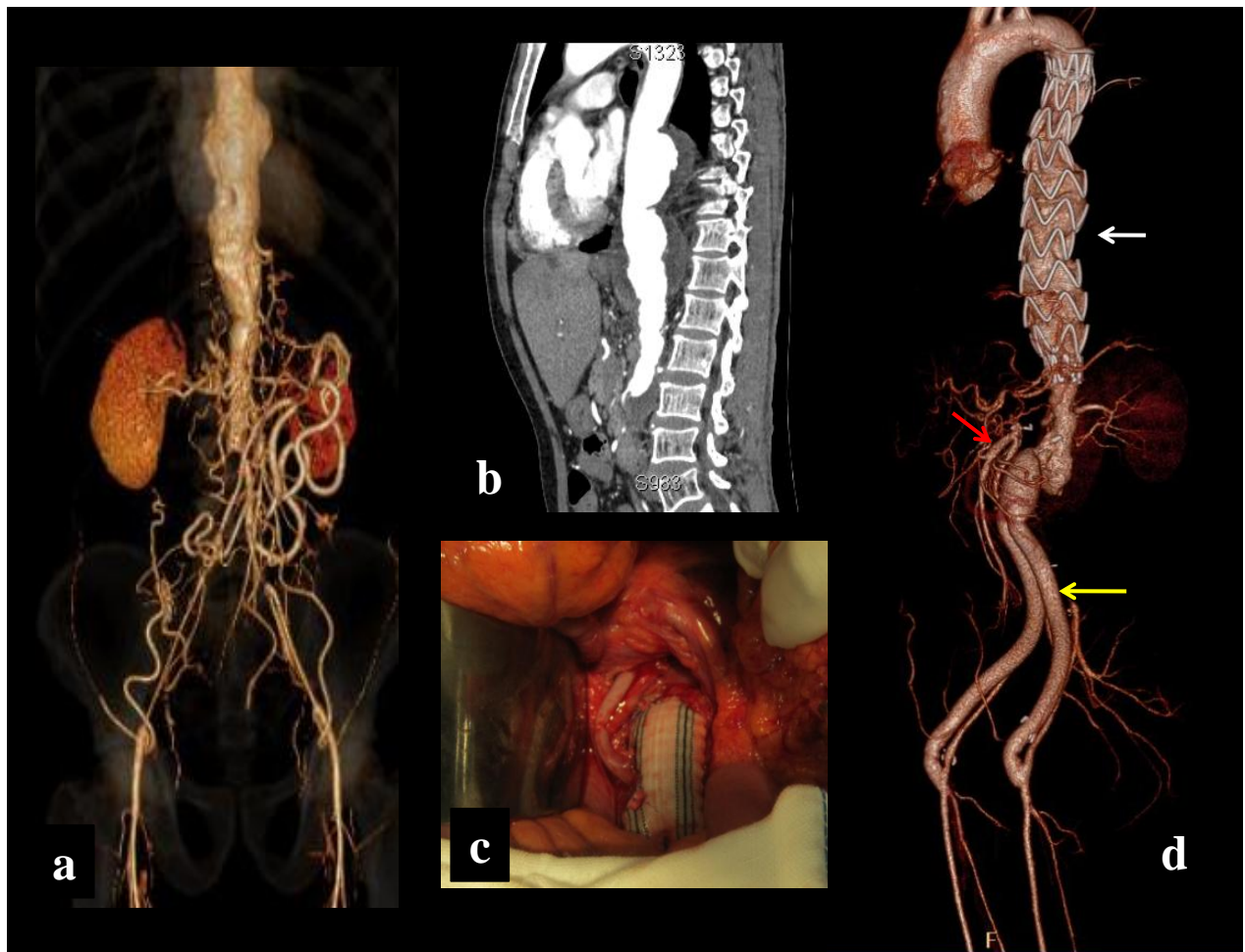
B: CT angiogram, volume-rendered 3D image showing residual aortic arch and DTA dissection with aneurysmal degeneration (yellow arrow) following prior graft replacement of ascending aorta (white arrow) for type A aortic dissection.

C: Digital subtraction angiogram prior to stent graft deployment showing patent grafts from ascending aorta with 10mm graft to right CCA (black arrow), piggy backing an 8mm graft to left CCA (white arrow), and another 8mm graft to left SCA (red arrow). Native stumps of the debranched arch vessels are seen (blue arrow).

D: Check angiogram after stent graft deployment

E: CT angiogram, volume-rendered 3D image at 1 year follow-up showing patent bypass grafts, significantly remodelled aorta, and near-total thrombosis of false lumen

Figure 6: Synchronous repair of Type I Thoraco-abdominal aortic aneurysm with concomitant Aorto-iliac and mesenteric occlusive disease



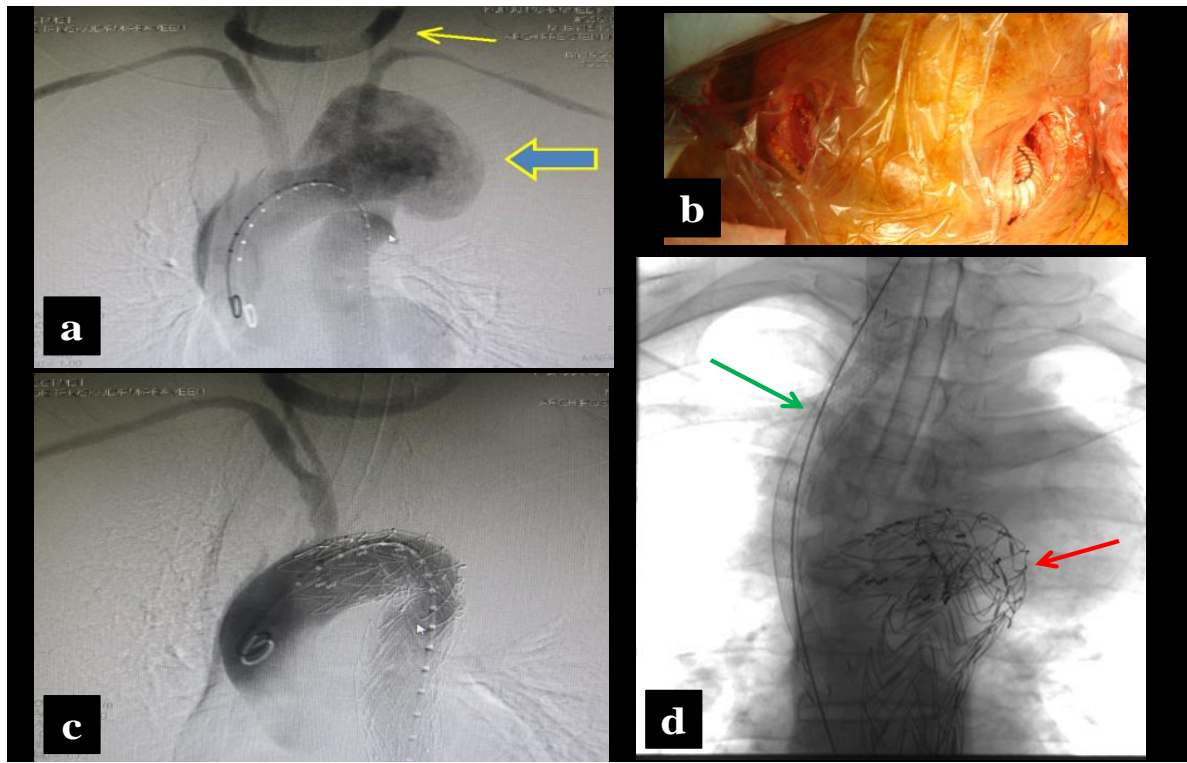
A: CT angiogram, VRT three dimensional image showing occlusion of ostio-proximal segments of celiac trunk and SMA, with total occlusion of infra-renal aorta extending to both common iliac arteries. Extensive mesenteric collateral noted with a large Arc of Riolan fed by inferior mesenteric artery with 70% ostial stenosis

B: CT, MPR image showing type I TAAA of maximum diameter 6.6cm

C: Per-operative photograph showing completed retrograde SMA bypass grafting using reversed saphenous vein from main body of polyester graft used for aorto-bifemoral bypass

D: CT angiogram, volume rendered three dimensional image at 6-month follow-up showing well apposed stent-graft (white arrow) in the thoraco-abdominal aorta and patent aorto-bifemoral (yellow arrow) and mesenteric bypass (red arrow) grafts.

Figure 7: Emergent hybrid repair of ruptured aortic arch aneurysm with Aorto-Esophageal fistula



A: Digital subtraction angiogram through marker pigtail catheter demonstrating large 8.5cm aneurysm in the distal aortic arch (blue arrow). Patent carotid-carotid bypass graft is also visualised

B: Intra-operative photograph after completion of carotid-carotid bypass with 8mm polyester graft (necklace procedure)

C: Digital subtraction angiogram at completion of stent-graft deployment showing excluded aneurysm with normal flow through innominate artery (procedure required a additional stent-graft to tackle Type III endoleak

D: Post-procedure fluoroscopy image showing 36x167mm and 34x167mm Medtronic Valiant Thoracic aortic stent-grafts (red arrow) and esophageal cover stent (green arrow) in situ. Patient was kept nil orally and enteral feeding administered through feeding jejunostomy

LESSONS LEARNT

1. Meticulous pre-operative planning is a fundamental in the successful execution of open repair, and particularly endovascular/hybrid repair; so much that failing to plan is equivalent to planning to failure.
2. Use of CSF drainage, distal perfusion and inclusion of intercostal artery has contributed significantly for reducing the risk of spinal cord ischemia in open repair.
3. Obligatory proximal sealing zone of 3cm ideally with horizontal lie in the arch is an important measure to abate long-term adverse outcomes like migration, endoleak and retrograde aortic dissection for both degenerative aneurysm of arch as well as Stanford B aortic dissection.
4. Intentional coverage of left subclavian artery is safe and well tolerated, although in specific situations a proactive bypass is mandatory to avoid devastating posterior circulation, spinal cord or upper limb ischemia.
5. Stent-grafts with proximal bare-springs are better avoided in case of acute aortic dissections in view of the real hazard of retrograde aortic dissection.
6. Staging of hybrid repairs by 1 or 2 days is preferable to limit physiological insult to the patient and allow for haemostasis and system recovery.
7. Patients in the subset of ruptured thoracic aortic pathologies have immensely benefitted with tremendous survival benefit and excellent quality of life.



Technical Advisory Committee (Clinical Studies)
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES & TECHNOLOGY
THIRUVANANTHAPURAM – 695011, INDIA

TAC Registration No: SCT-/S/2014/298

Date: 20.01.2015

Project title: Spinal protection during management of thoracic aortic pathologies - Recent experiences with open repair and endovascular stent grafting

Principal Investigator:	
Name: Dr. Ajay	Degree: M.S
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Members who participated in the TAC meeting on 03/01/2015

Dr. Sanjeev V Thomas (Chairman)
 Dr. Lissy K Krishnan
 Dr. Bejoy Thomas
 Dr. Biju Soman
 Dr. Thomas Koshy
 Dr. Mathew Abraham
 Dr. K. Shivakumar (Member Secretary)

Risk Classification of the project (Minimum/ Moderate/ High): Minimum

Requirement of DSMB: No

Recommended members of DSMB: Not applicable

Recommendations of TAC:

Recommended for consideration of IEC in the light of the responses received from the investigator.

The PI may note that there can be no additions / alterations in the documents approved by TAC when they are submitted to the IEC.

Signature of the Member Secretary, TAC (Clinical Studies)

Note for IEC

Copy of the investigator's responses to questions/suggestions from TAC is attached (Appendix-1).

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान
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(An Institute of National importance under Govt. of India)



Institutional Ethics Committee
(IEC Regn No. ECR/189/Inst/KL/2013)

SCTMEC/723/FEBRUARY -2015

12-03-2015

Dr. Ajay
Senior Resident
Department of CVTS
SCTIMST, Thiruvananthapuram

Dear Dr. Ajay,

The Institutional Ethics Committee reviewed and discussed your application to conduct the study entitled "SPINAL PROTECTION DURING MANAGEMENT OF THORACIC AORTIC PATHOLOGIES - RECENT EXPERIENCES WITH OPEN REPAIR AND ENDOVASCULAR STENT GRAFTING (IEC/723)" on 21st February, 2015.

The following documents were reviewed:

Original submission

1. Covering letter addressed to the Chairperson, IEC, SCTIMST.
2. IEC application form.
3. TAC Approval Letter.
4. Declaration form
5. Study proposal.
6. TAC Application form
7. Copy of investigators response to queries from TAC.
8. Observation chart.
9. Consent form in English and Malayalam.
10. Short CVs of PI and Co-PIs.

Revised submission

11. Covering letter addressed to the Chairperson, IEC, SCTIMST dated 11.03.2015.
12. Modified Application Form is submitted.

Page 1 of 2

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The following members of the Ethics Committee were present at the meeting held on 21st February, 2015 at G. Parthasarathi Board Room, AMCHSS, SCTIMST.

SL. No.	Member Name	Highest Degree	Gender	Scientific /Non Scientific	Affiliation with Institution(s)
1.	Justice Gopinathan. P.S	BSc. LLB	Male	Legal Expert (Chairperson)	No
2.	Dr. J. M. Tharakan	MD	Male	Clinician (Cardiologist)	Yes
3.	Shri. O.S. Neelakandan Nair	BE	Male	Engineer	Yes
4.	Dr. Meenu Hariharan	DM	Female	Clinician (Gastro-Enterologist)	No
5.	Dr. R V G Menon	PhD	Male	Lay Person	No
6.	Dr. Rema M. N	MD	Female	Pharmacologist	No
7.	Dr. Kala Kesavan. P	MD	Female	Pharmacologist	No
8.	Dr. Mala Ramanathan	MSc, PhD, MA	Female	Ethicist/Social Scientist (Member Secretary)	Yes

IEC Decision

The IEC approved the conduct of the study in the present form.

Remarks:

The Institutional Ethics Committee expects to be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent and asks to be provided a copy of the final report.

There was no member of the study team who participated in voting / decision making process. The ethics committee is organized and operated according to the requirements of Good Clinical Practice and the requirements of the Indian Council of Medical Research (ICMR).

Sincerely,



Mala Ramanathan
Member Secretary, IEC

THESIS_Ajay.doc

ORIGINALITY REPORT

14%

SIMILARITY INDEX

PLAGIARISM CHECK DOCUMENT

PRIMARY SOURCES

1	Koichi Tabayashi. "Spinal Cord Protection During Thoracoabdominal Aneurysm Repair", Surgery Today, 01/2005 CrossCheck	775 words — 7%
2	admin.vascularweb.org Internet	102 words — 1%
3	vascular.stanford.edu Internet	63 words — 1%
4	www.ncbi.nlm.nih.gov Internet	61 words — 1%
5	Luehr, Maximilian, Aida Salameh, Josephina Haunschild, Alexandro Hoyer, Felix F. Girrbaach, Konstantin von Aspern, Stefan Dhein, Friedrich-Wilhelm Mohr, and Christian D. Etz. "Minimally Invasive Segmental Artery Coil Embolization for Preconditioning of the Spinal Cord Collateral Network Before One-Stage Descending and Thoracoabdominal Aneurysm Repair .", Innovations Technology and Techniques in Cardiothoracic and Vascular Surgery, 2014. CrossCheck	53 words — 1%
6	evascular.com.au Internet	33 words — < 1%
7	Cambria, R.P.. "Prevention of spinal cord ischaemic complications after thoracoabdominal aortic surgery", European Journal of Vascular & Endovascular Surgery, 199802 CrossCheck	29 words — < 1%

“Spinal protection during management of thoracic aortic pathologies - Recent experiences with open repair and endovascular stent grafting”

BIODATA:

S.NO:

Name of the patient:

Age:

Sex:

Hospital number:

Contact Details:

Diagnosis:

Date of Procedure:

RISK FACTORS AND CO-MORBIDITIES: (Tick if present)

Hypertension Diabetes mellitus Smoking history Dyslipidemia

Coronary artery disease Chronic obstructive pulmonary disease Renal

dysfunction

Cerebrovascular disease

Peripheral arterial disease

H/o previous aortic repair: _____

Procedural details

A) TEVAR Group	Tick Mark Appropriate
• Timing: Elective/Emergency for TEVAR	Elective/Emergency
• Diameter of aneurysm/dissected aorta
• Stent-graft used and size and length covered
• Coverage of Lt subclavian artery	YES/NO
• Access vessel used (Native CFA/conduit)	Native CFA/conduit
• Proximal and distal zones of deployment
• Anaesthesia employed during TEVAR	GA/LA
• CSF Drainage	YES/NO
• Mean arterial pressure monitoring

B) OPEN REPAIR GROUP

- Site of proximal and distal anastomosis (Extent of disease which needs treatment)
.....
- Perioperative maintenance of haemodynamics -Mean arterial pressure of 90mmHg
.....
- Distal perfusion strategy- Temporary Aorto-femoral bypass
.....
- Implantation of intercostals arteries
.....
- Bevelling of anastomosis to include intercostals arteries
.....
- Pharmacology strategies- Mannitol, steroids, thiopentone sodium
.....
- Cell saver/Retrieval system use for rapid autologous blood transfusion
.....

PERI-OPERATIVE DETAILS (30- day):

Mortality

Stroke

Paraplegia/Paraparesis

Renal failure (Requiring dialysis)

Transient renal dysfunction

Myocardial infarction

Respiratory failure

Visceral ischemia

Stentgraft migration:

Endoleaks (If yes, Type: _____)

Access related complications: _____

Wound infection:

Length of hospital stay: _____

Signature of the investigator:

OPEN SURGICAL REPAIR GROUP													
Sr.no	Age	Sex	Diagnosis	DM	HTN	CAD	PAD	Complications	Paraplegia	Mortality	DISTAL PERFUSION	intercostal reimplantation	Bevelled anastomosis for intercostal inclusion
1	57	m	DFA ty A	-	-	-	-	-	n	-	DCA, CSF drain	Y, d8 level	-
2	54	m	Ty III TAAA	-	+	+	-	ARDS, ilous	n	Expired	AF bypass, CSF drain	-	-
3	60	m	Ty III TAAA	+	+	-	-	ARF	n	-	AF bypass, CSF drain	-	yes proximal
4	44	m	Ty I TAAA	-	+	-	-	ARF	n	-	AF bypass, CSF drain	-	yes distal
5	59	m	Ty V TAAA	-	+	-	-	ARF	n	-	AF bypass, CSF drain	-	-
6	50	m	Ch Ty B AD	+	+	-	+	post op seizures/ cerebral edema	n	-	DCA, CSF drain	-	-
7	62	m	Ty V TAAA	-	-	-	+	-	n	-	AF bypass, CSF drain	-	-
8	64	m	Ty II TAAA	+	+	-	+	ARF, MODS	Y on pod 1	Expired	TCA, CSF drain	-	-
9	63	m	Ty IV TAAA	-	-	-	-	-	n	-	AF bypass, CSF drain	-	-
10	48	m	Ty III TAAA	-	-	-	-	ARF	n	-	AF bypass, CSF drain	-	-
11	46	m	DFA ty C	-	-	-	-	-	n	-	AF bypass, CSF drain	-	-
12	42	m	Ch Ty B AD	-	+	+	-	-	n	-	DCA, CSF drain	-	-
13	52	m	Ch Ty B AD	-	+	-	+	-	n	-	DCA, CSF drain	-	-
14	53	m	DFA ty C	-	-	-	-	Post op bleed	n	Expired	AF bypass, CSF drain	Y, d8 level	-
15	66	m	DFA ty B	+	+	+	-	Resp infection	n	-	AF bypass, CSF drain	Y	-
16	55	m	Ch Ty B AD	-	+	-	-	Postop stroke	n	-	DCA, CSF drain	-	-
17	62	m	Ty III TAAA	-	-	-	-	Sepsis, GB & Spleen gangrene	n	Expired	AF bypass, CSF drain	-	-
18	55	m	Ty IV TAAA	-	-	-	-	Post bowel gangrene, pancreatitis, gangrenous cholecystitis	n	-	AF bypass, CSF drain	-	-
19	63	m	Ty III TAAA	+	-	-	-	Septicemia	n	Expired	AF bypass, CSF drain	Y, 3 d8 level	-
20	50	m	Ty III TAAA	-	-	-	-	ARF, Ili renal artery occlusion	n	-	AF bypass, CSF drain	-	yes proximal
21	65	m	Ty III TAAA	+	-	-	-	-	n	-	AF bypass, CSF drain	-	-
22	41	m	Ch Ty B AD	-	+	-	-	-	n	-	DCA, CSF drain	-	-
23	59	m	Ty V TAAA	-	-	-	+	-	n	-	AF bypass, CSF drain	-	-
24	78	m	Ty I TAAA	-	-	+	-	ARF	n	-	AF bypass, CSF drain	Y, d8 level	-
25	69	m	Ty IV TAAA	-	-	-	-	post op bleeding	n	Expired	AF bypass, CSF drain	Y, 2 T8 level	-
26	49	m	Ty V TAAA	-	+	-	+	ARF	n	-	AF bypass, CSF drain	-	-
27	61	m	Ty III TAAA	+	+	-	-	ARF/AF	n	-	AF bypass, CSF drain	-	-
28	58	m	Ty III TAAA	-	+	-	-	tracheostomy	n	-	AF bypass, CSF drain	-	-
29	45	m	Ty V TAAA	-	+	-	-	ARF, Ili renal artery stenosis-DSA done after 5 months	n	-	AF bypass, CSF drain	Y, one d8	-

TEVAR/HYBRID TEVAR GROUP

S No	Age	Sex	Diagnosis	Co-morbidities	Procedure	Elective/ Emergenc y	Hybrid (Y/N)	Stage I procedure	Interva I	LSA Coverage	Zone of depl oym ent	Anesthes ia	CSF drain	No of endografts	Peri-op Complications	Cause of death (if expired)
1	54	M	Type 5 TAAA	HTN, smoker	TEVAR	2	N	NA	NA	No	4	LA	N	1	Esophageal erosion stented	-
2	69	M	DTAA Type C, S/P SMA and B/L RA stenting	HTN, COPD, smoker	TEVAR	1	N	NA	NA	No	3	GA	N	2	Transient CIN	-
3	70	M	Type B AD	HTN, CAD, smoker	TEVAR	1	N	NA	NA	No	3	LA	N	2	CIN	-
4	61	M	Distal Ao arch aneurysm	HTN, DM, smoker	TEVAR	1	Y	Ao-LTCCA	5	Yes	1	GA	N	1	Nil	-
5	79	M	DTAA Type B	HTN, smoker	TEVAR	1	N	NA	NA	No	4	LA	N	1	CIN	-
6	20	M	Traumatic DTA rupture	Nil	TEVAR	2	N	NA	NA	Yes	2	GA	N	1	Nil	-
7	71	M	Arch + DTAA	HTN, smoker	TEVAR	1	Y	Ao-BICCA + LT SCA	4	Yes	0	GA	Y	2	PARAPLEGIA, Resp Failure	-
8	64	M	DTAA (sacular)	DM, HTN, smoker, CAD	TEVAR	1	N	NA	NA	No	4	GA	N	1	Nil	-
9	53	M	Contained type V aneu rup	Smoker, HTN, bipolar	TEVAR	2	N	NA	NA	No	4	GA	N	1	CIN	-
10	70	M	Ao arch aneurysm + DTAA	DM, HTN, COPD, smoker	TEVAR	1	Y	Ao-BICCA + LT SCA	1	Yes	0	GA	Y	2	In hospital /mortality + paraplegia	Respiratory failure + Paraplegia
11	44	M	Type3 AD	Nil	TEVAR	1	Y	Ao-LTCCA	1	Yes	1	LA	N	1	Nil	-
12	49	M	post open repair of type3 AD - distal anastomotic leak into false lumen - DTAA	HTN	TEVAR	1	N	NA	NA	No	4	LA	N	1	Nil	-
13	70	M	Ruptured TAAA	HTN, CKD, COPD, smoker	TEVAR	2	N	NA	NA	No	4	GA	Y	1	Mortality	Acute on chr failure
14	67	M	Progressive Arch and DTA dissection S/P Type A repair	HTN	TEVAR	1	Y	Ao-BICCA + Lt SCA	4	Yes	0	LA	N	1	CIN	-
15	56	M	Ruptured DTAA	HTN, smoker	TEVAR	2	N	NA	NA	No	4	LA	N	1	CIN	-
16	66	M	Type C DTAA	HTN, CAD, smoker	TEVAR	1	N	NA	NA	No	4	GA	N	1	Nil	-
17	64	M	Ruptured Type 5 TAAA, S/P AF bypass	HTN, smoker	TEVAR	2	N	NA	NA	No	4	LA	N	1	Nil	-
18	55	M	Ruptured Distal arch/upper DTA aneurysm + AEF	HTN, COPD, smoker	TEVAR-Esophag eal stent	2	Y	C-C	0	Yes	1	GA	N	2	Nil	-
19	49	M	type 3B aortic dissection	smoker, HTN	TEVAR	2	Y	C-C	0	Yes	1	GA	N	1	CIN	-
20	51	M	type 3B aortic dissection	HTN	TEVAR	1	N	NA	NA	No	4	LA	N	1	Nil	-
21	23	M	POST TRAUMA-DTA PSA	Nil	TEVAR	2	N	NA	NA	Yes	2	GA	N	1	CIN	-
22	78	M	DTA SACULAR	HTN	TEVAR	1	N	NA	NA	No	4	LA	N	1	Nil	-
23	70	M	DTA SACULAR	N, smoker, CAD, COPD, Mild C	TEVAR	1	N	NA	NA	No	4	LA	N	1	Nil	-
24	73	M	DISTAL ARCH	CAD, HTN, \$\$\$	TEVAR	1	Y	C-C	1	Yes	1	LA	N	1	Nil	-
25	44	M	Type 3B aortic dissection	HTN	TEVAR	1	N	NA	NA	No	3	LA	N	1	Nil	-
26	40	F	TYPE 3B AD WITH RETROGRADE ARCH DISSECTION	HTN	TEVAR	1	Y	Ao-BICCA + LT SCA	1	Yes	0	LA	N	1	Nil	-
27	56	M	TYPE 5 TAAA, AAA	HTN, smoker	TEVAR	1	N	NA	NA	No	4	LA	N	1	Nil	-
28	69	M	DISTAL ARCH	HTN, smoker	TEVAR	1	Y	C-C	1	Yes	1	LA	N	1	Nil	-

29	38	F	ASC AORTIC ANEURYSM, TYPE B AD	HTN	BENTALL + TEVAR	1	Y	AO-L1 CCA	1	Yes	1	LA	N	1	NIL	-
30	72	M	DISTAL ARCH	HTN, smoker	TEVAR	1	Y	AO-L1 CCA	270	Yes	1	LA	N	1	NO	-
31	70	M	DISTAL ARCH	HTN, smoker	TEVAR	1	Y	C-C	1	Yes	1	LA	N	1	NIL	-
32	56	M	POST TRAUMA-AR, DTA, PSA	NIL	+ MV repair + TE	2	Y	AO-L1 CCA	0	Yes	1	GA	N	1	CIN	-
33	55	M	RUPTURED TYPE B AD	HTN, smoker	TEVAR	2	Y	C-C	0	Yes	1	GA	N	1	NIL	-
34	49	F	TYPE B AD	HTN, DM	TEVAR	1	Y	AO-L1 CCA	0	Yes	1	GA	N	1	NIL	-
35	47	M	Type A DTA aneurysm rupture	HTN	TEVAR	2	N	NA	NA	No	4	LA	N	1	CIN	-
36	69	M	Pseudoaneurysm DTA, Aorta-Bronchial fistula	HTN, DM, smoker	TEVAR	2	M	NA	NA	No	4	LA	N	1	NIL	-
37	72	M	Distal arch + DTA aneurysm	DM, HTN, smoker	TEVAR	1	Y	C-C	1	Yes	1	LA	N	1	NIL	-
38	87	M	Type V TAAA leaking	HTN, smoker	TEVAR	2	N	NA	NA	No	4	LA	N	1	CIN	-
39	62	M	Type V TAAA	HTN, smoker, CAD	TEVAR	1	N	NA	NA	No	4	LA	N	1	NIL	-
40	71	M	Distal arch aneurysm	HTN, smoker, CAD	TEVAR	1	Y	C-C	1	Yes	1	LA	N	1	NIL	-
41	40	M	Type B AD	HTN	TEVAR	1	Y	AO-L1 CCA	1	Yes	1	LA	N	1	Mortality	Visceral
42	60	M	Type V TAAA + AI block + Occluded Celiac and SMA	HTN, smoker	TEVAR + AF and SMA bypass	1	Y	ABF bypass +SMA bypass	1	No	4	LA	N	1	Aspirin induced GI bleed	-
43	68	M	Chronic type B AD with TAAA	HTN, smoker, COPD	TEVAR	1	Y	C-C	1	Yes	1	LA	N	1	NIL	-
44	50	F	Type B AD with rupture	HTN	TEVAR	2	N	NA	NA	No	3	LA	N	1	CIN	-
45	37	F	Progressive Arch and DTA dissection S/P Type A repair	HTN	TEVAR	1	Y	AO-BICCA + BISCA	1	Yes	0	GA	N	1	NIL	-
46	28	F	Type A AD with left pleural rupture	HTN	TEVAR	2	Y	C-C	0	Yes	1	GA	N	1	CIN	-
47	42	M	Atypical Type B AD	HTN, CKD, renal A stenosis	TEVAR	1	N	NA	NA	No	4	LA	N	1	NIL	-
48	65	M	Saccular lower DTA aneurysm	HTN, CP angle tumour, PCA	TEVAR	1	N	NA	0	No	4	LA	Y	1	NIL	-
49	72	M	Type B DTA aneurysm	HTN	TEVAR	1	N	NA	0	No	4	GA	N	1	CIN	-
50	60	M	Type C DTAA	HTN	TEVAR	1	N	NA	0	No	3	GA	Y	2	NIL	-
51	72	M	Atypical Type B AD	HTN	TEVAR	1	N	NA	0	No	4	GA	Y	1	NIL	-
52	71	M	Type V TAAA	HTN	TEVAR	1	N	NA	NA	No	4	GA	N	1	NIL	-
53	38	M	DTAA Type B rupture	HTN	TEVAR	2	N	NA	NA	No	4	GA	N	1	right groin	-
54	71	M	DTAA Type A with arch aneurysm	HTN, CAD, COPD	TEVAR	1	Y	C-C< SCA BX	1	YES	1	GA	N	2	right groin	-
55	65	M	Chronic type B AD with atypical lower entry point	HTN	TEVAR	1	Y	ILO- MESPENTERIC	1	No	3	GA	N	2	abdominal dehiscence	-
56	75	M	Type V TAAA+	HTN, CKD, CA Rectum treated, asthma	TEVAR	2	N	NA	no	No	3	GA	Y	2	CKD,MI/IO,SEIZURE	-
57	66	M	Type V	HTN	TEVAR	1	N	NA	NA	No	4	GA	Y	2	CIN	-
58	59	M	DTAA-A	HTN,DM,CLD	TEVAR	1	N	NA	NA	YES	2	GA	N	1	NIL	-
59	62	M	Chronic type B AD	HTN	TEVAR	1	N	NA	NA	Yes	2	GA	Y	1	CIN	-
60	74	M	DTAA type B, ruptured(PAU)	HTN,COPD	TEVAR	2	N	NA	NA	No	3	GA	Y	1	Hemothorax drainage	-
61	55	M	Chronic type B AD	HTN	TEVAR	1	Y	C-C	1	Yes	2	GA	N	1	NIL	-
62	60	M	DTAA type A equivalent	HTN	TEVAR	2	N	NA	NA	No	3	GA	Y	2	Expirid, CKD, Upper GI bleed	Expirid, CKD, Upper GI bleed

LIST OF ABBREVIATIONS

TAAA	-	Thoracoabdominal aortic aneurysm
DTA	-	Descending Thoracic Aorta
DTAA	-	Descending Thoracic Aortic aneurysm
CSF	-	Cerebrospinal Fluid
CSFD	-	Cerebrospinal Fluid Drainage
TEVAR	-	Thoracic EndoVascular Aortic Repair
CFA	-	Common Femoral Artery
CCA	-	Common Carotid Artery
LSCA	-	Left Subclavian Artery
GA	-	General Anaesthesia
LA	-	Local Anaesthesia
BAI	-	Blunt Aortic Injury
TBAD	-	Type B Aortic Dissection
COPD	-	Chronic Obstructive Pulmonary Disease
CAD	-	Coronary Artery Disease
PAD	-	Peripheral Artery Disease
CVD	-	CerebroVascular Disease
DM	-	Diabetes Mellitus
HTN	-	Hypertension
FL/TL	-	False Lumen/True lumen
CKD	-	Chronic Kidney Disease
CIN	-	Contrast Induced Nephropathy

RRA	-	Right Renal Artery
LRA	-	Left Renal Artery
CPB	-	Cardio-Pulmonary bypass
RCT	-	Randomized Controlled Trial
DHCA	-	Deep Hypothermic Circulatory Arrest
VRT	-	Volume Rendered Technique
MPR	-	Multi Planar Reconstruction