

Investigational Device Exemption Application

Endovascular Exclusion of Abdominal Aortic Aneurysms in High Risk Patients

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Background

Many studies have reported on the safety and efficacy of endovascular aneurysm repair over the past eight years. As endovascular grafting has evolved, its applicability has increased substantially. However, it remains difficult to establish defined criteria for patient selection, largely due to the rapidly changing technology available. The device to be studied in this proposal is the product of a world wide collaborative effort to provide an endoluminal prosthesis that is easily and safely deployed to provide complete and durable aneurysm exclusion. All non-clinical testing was performed in the United States was performed to comply with the Good Laboratory Practice regulations.

The device to be tested has been in use in Perth Australia since 1994^{1,2}, having evolved in parallel with devices in Sweden³⁻⁶, England⁷, and the United States^{8,9}. The one-time aorto-uniiliac device is now a modular bifurcated system. The delivery device has decreased substantially in size while providing an increased degree of flexibility. The proximal aortic attachment site more closely resembles an anastomotic equivalent. The device, throughout its evolution, has been placed in over 500 patients, however experience with the bifurcated version of this graft is limited to 108 patients². Several recent modifications, particularly with regard to delivery mechanisms and the modular configurations have been made in an effort to broaden the selection criteria and prevent some of the long-term complications encountered with other types of endovascular grafts.

Of the 108 patients receiving bifurcated endografts in Perth, successful deployment was achieved in 103 patients (95 percent) with a median follow-up period of 18 months. There were 9 cases (8.3 percent) of primary endoleak (defined as an endoleak detected on CT scanning prior to hospital discharge). However, 15 endoleaks (13.8 percent) were noted at the six-week follow-up evaluation, inclusive of the original 8.3 percent. Of this group, 7 patients (47 percent) were successfully treated with adjuvant endovascular procedures, 4 (26 percent) sealed spontaneously, 2 patients died of unrelated causes, and 2 endoleaks remain under close observation. Three patients (2.7 percent) presented with limb occlusion during the follow-up period. Of the original 108 patients, 91 are still alive. Twelve deaths were secondary to unrelated causes, and the causes of two deaths are unknown. Two perioperative deaths occurred attributed to the procedure, and one patient died of mesenteric ischemia following endoluminal repair². Overall, the results compare favorably with historical surgical controls.

Experience with regard to the use of endografts at the University of Rochester includes participation in the Vanguard trial run by Boston Scientific – Meadox. This involved the placement of both modular bifurcated devices and tube grafts in 20 patients. We are currently participating in the Talent trial, and a number of homemade stent-grafts have been placed on a compassionate basis.

1.0 Purpose

The purpose of this study is to assess the role of abdominal aneurysm exclusion using an endovascular prosthesis.

1.1.0 Objectives

- 1) To assess the safety and efficacy of an endovascular prosthesis as a means of preventing aneurysm growth and rupture in high-risk patients.
- 2) To measure the physiologic effects and outcomes of endovascular aneurysm repair.
- 3) Establish selection criteria, improve device design, operative technique and follow-up procedures for patients undergoing endovascular aneurysm repair.

1.2.0 Duration of Investigation

Duration of the investigation will include a twenty-four month follow-up period, however, the patients will be followed for their lifetime with regard to the continued assessment of endovascular aneurysm exclusion and risk for rupture.

2.0 Characteristics of the Research Population

- 1) Number of subjects. A total of 300 high risk patients will be enrolled in this study. The study will be conducted at the Cleveland Clinic Foundation. Enrollment will be on a rolling basis.
- 2) Gender of subjects. Gender is not an issue in this study. Enrollment will occur on a rolling basis regardless of gender.
- 3) Age of subjects. Subjects must be over 18 years of age. There is no maximum age however, patients must have an approximated life expectancy greater than 2 years.
- 4) Racial and ethnic origin. Racial and ethnic origin is not an issue in this study.
- 5) Inclusion criteria

General:

- a) the aneurysm is 5 cm or larger, or with a high risk of rupture due to its shape, history of growth, symptoms, or the presence of a large (>3.5 cm) iliac aneurysm
- b) anticipated mortality greater than 10 percent with conventional surgery*
- c) life expectancy greater than 2 years
- d) suitable arterial anatomy
- e) absence of systemic disease or allergy that precludes an endovascular repair
- f) capable of giving informed consent and willingness to comply with the follow-up schedule

* The risk of death following conventional operation (called “anesthetic risk”, although this is more closely related to the effects of surgery) will be determined primarily by the extent of co-morbid conditions, particularly cardiopulmonary disease. Clinical assessment will be determined in concert with medical and anesthesiology consultants when needed. Many factors weigh into the determination of operative risks. There are a wide variety of methods for attempting to quantify the relative effects of each risk factor however this has been done without reproducibility. In addition to the anesthetic risk, this analysis takes into account other risk factors for open surgical repair, such as retroperitoneal fibrosis, inflammatory bowel disease, prior radiation therapy, intestinal fistulae, and prior surgical procedures, all of which may complicate conventional surgical repair.

Anatomic:

- a) proximal neck > 10mm in length, \leq 32mm in diameter, and angulated no more than 80 degrees relative to the long axis of the aneurysm
- b) iliac artery diameter > 7mm (following balloon angioplasty or stenting if necessary)
- c) no signs that the inferior mesenteric artery is indispensable. These include angiographic visualization of a large IMA, filling of SMA via collaterals, or significant stenoses of the celiac or SMA.
- d) iliac artery angulation < 90 degrees. In the presence of significant calcifications, the angle should be less than 60 degrees.
- e) for a straight aorto-aortic prosthesis, the distal neck (normal aorta between the aneurysm and iliac bifurcation) must be greater than 15mm in length, and less than 26mm in diameter.
- f) for a bifurcated aorto-biiliac prosthesis, the iliac implantation sites must be less than 2 cm in diameter and greater than 2 cm in length.

6) Exclusion criteria

- a) pregnancy
- b) history of anaphylactic reaction to contrast material with an inability to properly prophylax the patient appropriately
- c) allergy to stainless steel or polyester
- d) unwilling to comply with the follow-up schedule
- e) serious or systemic groin infection
- f) coagulopathy, other than coumadin therapy
- g) inability to give informed consent

7) Vulnerable subjects. Subjects must be older than 18 years of age and capable of giving informed consent

3.0 Methods and Procedures

3.1.0 Study Design

This study will be a prospective, non-randomized evaluation of endovascular aneurysm repair in high-risk patients.

Patients will be selected based upon the following criteria:

- Patients will be considered high risk if they meet any of the “General Inclusion Criteria”
- Patients will be considered anatomically suitable if they fulfill all of the appropriate “Anatomic Inclusion Criteria”

Patients must meet both the general and anatomic criteria to be enrolled in the study. General inclusion criteria will be assessed during the initial patient evaluation by conducting a history and physical examination. Anatomic criteria will be assessed using a variety of imaging techniques that are routinely performed during the evaluation of abdominal aortic aneurysms (see appendix A: Imaging Techniques Summary). The choice of axial imaging technique will be left up to the referral physician provided that the imaging protocol utilized is adequate for complete preoperative planning as defined in Appendix 1. Angiography and intravascular ultrasound will be performed selectively as is currently done prior to infrarenal abdominal aneurysm repair.

3.1.1 Inclusion Criteria – High Risk Patients

- a) the aneurysm is 5 cm or larger, or with a high risk of rupture due to its shape, history of growth, symptoms, or the presence of a large (>3.5 cm) iliac aneurysm
- b) anticipated mortality greater than 10 percent with conventional surgery*
- c) life expectancy greater than 2 years
- d) suitable arterial anatomy
- e) absence of systemic disease or allergy that precludes an endovascular repair
- f) capable of giving informed consent and willingness to comply with the follow-up schedule

3.1.2 Exclusion Criteria

- a) pregnancy
- b) history of anaphylactic reaction to contrast material with an inability to properly prophylax the patient appropriately
- c) allergy to stainless steel or polyester
- d) unwilling to comply with the follow-up schedule
- e) serious or systemic groin infection
- f) coagulopathy, other than coumadin therapy
- g) inability to give informed consent

3.1.3 *Anatomic Criteria*

- a) proximal neck > 10mm in length, <= 32mm in diameter, and angulated no more than 80 degrees relative to the long axis of the aneurysm
- b) iliac artery diameter > 7mm (following balloon angioplasty or stenting if necessary) and < 20mm
- c) no signs that the inferior mesenteric artery is indispensable. These include angiographic visualization of a large IMA, filling of SMA via collaterals, or significant stenoses of the celiac or SMA.
- d) iliac artery angulation < 90 degrees. In the presence of significant calcifications, the angle should be less than 60 degrees.
- e) for a straight aorto-aortic prosthesis, the distal neck (normal aorta between the aneurysm and iliac bifurcation) must be greater than 15mm in length, and less than 26mm in diameter.
- f) for a bifurcated aorto-biiliac prosthesis, the iliac implantation sites must be less than 2 cm in diameter and greater than 2 cm in length.

3.1.4 *Stent-graft sizing*

Grafts are currently custom made for each patient based on the findings from preoperative radiologic studies, including computerized tomography, magnetic resonance imaging, and conventional angiography. See appendix A for a detailed protocol of the imaging studies to be obtained.

3.1.4.1 **Stent-graft diameter**

The diameter of the graft is intended to be 10 to 15 percent (usually 3-4 mm) larger than the proximal implantation site (see appendix B). The attachment site for distal implantation is oversized by 5 to 10 percent (see appendix C). The assumption being that a small amount of graft redundancy would be inconsequential, whereas, as small deficiency in the diameter of the graft would result in either endoleakage or graft migration.

Straight grafts (aorto-aortic) are of uniform diameter. The larger of the two implantation sites determines the diameter of the graft. Aorto-iliac grafts (uni-iliac and bifurcated devices) have different proximal and distal diameters. Additionally, bifurcated devices may have differently sized segments at the ends of their right and left limbs.

Determination of proximal graft diameter depends primarily on a measurement of the aneurysm neck from axial reconstructions of CT data. When the neck of the aneurysm appears to have an elliptical section on trans-axial images, the true profile is assumed to be circular, and the true diameter is the diameter of the

narrowest part of the ellipse. The elliptical appearance is thus reflective of the aortic tortuosity and obliquity of the slice.

3.1.4.2 Stent-graft Length

Given the tension of the graft at the time of distal stent implantation, it is assumed that the graft will take the shortest path available from the renal arteries to the aortic bifurcation. For straight aorto-aortic grafts, the prosthesis corresponds to the length of the infrarenal aorta. For aorto-iliac grafts, the distal implantation site is the common iliac artery; the graft length is such that the end of the graft is at least 2 cm from the aortic bifurcation while remaining 1 cm above the common iliac bifurcation. The primary imaging modality used to determine the length of the graft will vary depending on the tortuosity of the aorta and the availability of multiplanar reconstructions, surfaced shaded displays, and other representations of spiral CT data or angiographic images. Trans-axial CT images can be used for length assessment only when the aorta is relatively straight, the intervals between the slices small, and in the absence of good quality, properly calibrated angiographic images.

3.1.5 Device Manufacture and Sterilization

Cook Incorporated will manufacture the devices. I have no detailed information on the methods of manufacture. However, many features of the device are similar to the previous devices utilized at the University of San Francisco. Having already performed several aneurysm repairs with the Perth device Australia and Malmo, Sweden, I am very familiar with the most recent version. However, with regard to manufacturing details, I can do no better than to refer you to the most recent publication of the largest series of patients undergoing aneurysm repair with this device², included as appendix D. The device will not be sold. There will be no charge to patients for the use of the device.

Devices shipped under the Investigational Device Exemption are intended to be used for clinical studies in which waste will be controlled or the amount of waste expected to enter the environment may reasonably be expected to be nontoxic.

3.1.6 Stent-graft deployment

The procedure will be performed in the operating room under local, epidural or general anesthesia depending on patient factors. The patient will be positioned on a radiolucent operating table to permit fluoroscopic examination of the entire abdomen and groins. A high-resolution digital imaging system is required to guide placement. Other desirable imaging features include last image hold, digital subtraction, roadmapping, and hard copy output. Grafts may be inserted from either femoral artery with consideration given to the degree of tortuosity and occlusive disease noted from preoperative imaging techniques. The lower chest, abdomen and groins are prepared and draped in the usual sterile fashion. One common femoral artery is exposed and dissected free from surrounding structures using standard surgical techniques. A soft, relatively disease free portion of the anterior common femoral artery is selected for an arteriotomy. Double-looped tapes or vessel loops are used to encircle the common femoral or distal external iliac artery proximal and distal to the proposed site for arteriotomy. If the common femoral artery and external iliac arteries are too diseased to permit hemostasis using vascular loops, a short graft may be anastomosed to the femoral artery to serve as a conduit to the proximal arterial tree. Heparin is administered (100-150 units/kg) by intravenous injection 3 minutes prior to occlusion of the femoral artery. The loops are tightened to provide proximal hemostasis.

An angiographic catheter is passed through the femoral arteriotomy into the proximal aorta. An angiogram is performed. Using the angiogram as a reference, the limits of the proximal and distal cuffs are marked on the patient with a radio-opaque marker. Alternatively, the angiogram can be stored as a roadmap, to be superimposed on subsequent fluoroscopic images. Correct positioning of the prosthesis depends on the relationship of the imaging system to the patient. The angiographic catheter is then exchanged over a stiff guidewire for the delivery system. The system is advanced to bring the metal stents to the desired location. The position of the graft, as indicated by the position of the proximal and distal stents, can be maintained during extrusion by manipulation of the carrier. Assuming a bifurcated system is used, the femoral artery on the contralateral leg is then exposed. A steerable catheter and guidewire combination is used to cannulate the contralateral limb from within the aneurysm sac. The position of the catheter within the stent-graft is confirmed angiographically. Following complete deployment of the main stent-graft body, the contralateral limb is deployed over a stiff guidewire.

Withdrawing the sheath slowly over the carrier extrudes the main stent-graft and the contralateral limbs. It is easier to maintain the correct position of the graft if the hand controlling the carrier is braced upon the patient's leg. Throughout the procedure, angiographic evaluation can be intermittently assessed using the delivery sheath to administer contrast agent. Hemostasis is maintained by tension on the proximal loops, which compresses the common femoral arterial wall against the delivery system. Following graft deployment, the delivery system is removed through the femoral arteriotomy. Aortography is then performed with the intent of visualizing exclusion of the aneurysm sac. The presence of contrast material in the aneurysm sac is indicative of an endoleak, which may be treated at that time by modifications of the proximal or distal fixation points. Appendix D contains a more detailed and diagrammatic description of the procedure.

3.1.7 Perioperative Care

The endovascular method calls for no departure from the usual perioperative management of patients undergoing aneurysm repair. The preoperative evaluation and intraoperative monitoring will be performed as though the patient was undergoing conventional repair. Post-operative management will be dictated by clinical circumstances, and is likely to differ somewhat from the usual management of patients following aneurysm repair, because the patients tend to experience fewer physiologic derangements.

3.2.0 Data Analysis and Follow-up

3.2.1 Monitoring

A clinical study nurse will assist with the monitoring of study patients.

Clinical Study Nurse, personal information: Jennifer Hampton, RN
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3.2.2 Preoperative Assessment Data Points

Patients meeting the selection criteria who have provided informed consent will undergo a detailed preprocedural examination. Data will be collected and stored in a database. This database is constructed with the intent of capturing both study specific data, and information that will prove useful to our clinical practice, and research regarding the general subject of the endovascular management of aortic disease. Data collection will be simplified such that one basic form will obtain the majority of the necessary data for research, development, as well as compliance with both institutional and national study specific requirements. The sections that will not be viewed as study specific are shaded grey. Please refer to Appendix E for more detail. Data points include:

- 1) date of examination
- 2) date of hospital admission
- 3) age, sex, weight, and height
- 4) risk factors including:
 - a) smoking
 - b) diabetes
 - c) hypertension
 - d) cardiac disease
 - e) renal disease
 - f) pulmonary disease
- 5) prior peripheral vascular procedures
- 6) lower extremity pulse assessment or Doppler and ABI evaluation
- 7) radiographic results
 - a) proximal neck length, diameter, angulation
 - b) distal neck length, diameter, angulation
 - c) length of infrarenal aorta to be grafted
 - d) common iliac artery measurements
 - e) extent of visceral artery occlusive disease
- 8) baseline laboratory data

3.2.3 Intraoperative Data Points

The endovascular aneurysm procedure will be documented in such a way to permit analysis of any untoward occurrences in terms of cause and effect. Data will be collected and stored in a database. Data points include:

- 1) date of procedure
- 2) procedure time (skin to skin)
- 3) endoprosthesis time (from insertion of initial catheter to removal of the inner catheter of the delivery system)
- 4) contrast medium type and total volume infused
- 5) estimated blood loss
- 6) total amount of blood transfused and cell saver transfused
- 7) diameter, length and configuration of the prosthesis
- 8) assessment of system performance addressing: ease of insertion, accuracy of placement, ease of removal
- 9) ancillary equipment needed

- 10) adjunctive maneuvers including: balloon dilation of iliac arteries, additional stents required, additional surgical procedures, maneuvers to move or re-align stents, the need for thrombectomy
- 11) nature of completion assessment
- 12) findings of completion assessment: endoleak, kinks, twists, angulation of stents

3.2.4 Postoperative Course Data Points

The interval between deployment of the endoprosthesis and discharge from the hospital will be documented. Data points include:

- 1) date of discharge
- 2) survival or death – if the patient has died, a death form should be filled out
- 3) complications (if any)
- 4) patient withdrawal from study
- 5) postoperative imaging information: CT scan, KUB are mandatory
- 6) time to resumption of regular diet
- 7) time to first bowel movement
- 8) time to resumption of normal mobility
- 9) maximum daily temperature up to time of discharge or day 14
- 10) peripheral vascular exam at time of discharge including pulses or an ABI
- 11) blood tests at time of discharge (CBC, BUN, Cr)

3.2.5 Follow-up

The results of the endovascular repair will be assessed by radiologic and/or clinical criteria at the time of graft insertion, prior to hospital discharge, between two and four weeks at a follow-up appointment, and according to the postoperative imaging schedule listed below.

	Pre-op	Intra-op	Prior to d/c	1 month	6 month	12 months	24 month
CT Scan	X*		X	X	X	X	X
Angiography	X	X					
KUB			X	X	X	X	X

A series of blood tests including blood urea nitrogen, complete blood count, and creatinine will be obtained on the same schedule as the CT scans. Additional data points to be obtained during follow-up include:

- 1) date of follow-up
- 2) survival or death
- 3) complications (if any)
- 4) patient withdrawal
- 5) findings of any imaging abnormalities
- 6) peripheral vascular exam or ABI
- 7) blood test (CBC, BUN, Cr)

3.2.6 Adverse Events

3.2.6.1 Deaths

Details of any deaths occurring during the evaluation will be stored in a database. Data points include:

- 1) immediate cause of death
- 2) underlying cause of the fatal condition
 - a) related to the prosthesis
 - b) related to the procedure
 - c) related to a previous condition
- 3) status of the prosthesis at the time of death

3.2.6.2 Explants

Autopsy will be requested in all patients who die with a prosthesis in place. At the autopsy, the entire abdominal aorta will be excised – from the celiac axis down to and including both common iliac arteries. The specimen will undergo histologic examination.

When the prosthesis is excised in the course of conversion to open repair, the position, and attachment of the prosthesis within the arterial tree will be recorded. In addition, every care will be taken to ensure that the prosthesis is removed intact. For example, vascular clamps will be applied at remote sites from stent attachments. The prosthesis will then be washed with saline to remove surface thrombus. The graft components will be fixed in 4% formaldehyde for subsequent histologic examination. Data will be collected and stored in a database. Data points include:

- 1) date of explant
- 2) patient's status at explant
- 3) reason for explant
- 4) degree of attachment / ingrowth

3.2.6.3 Loss to Follow-up

If a patient is lost to follow-up, the following information will be recorded:

- 1) date of last contact with patient
- 2) reasons for patient's unavailability: withdrawal, moved away, unreachable, and so forth
- 3) summary of attempts to contact patient
- 4) name and address of any physician who is following the patient

4.0 Risk/Benefit Assessment

The device is an implantable endoprosthesis intended to prevent aneurysm rupture. The hazards associated can be categorized as material-related, insertion related, and performance related. The consequent risks to the patient depend on the incidence and effects of each hazard, which have been explored in a large number of experimental and clinical insertions^{1,2,10}. These risks of endovascular aneurysm repair must be weighed against the risks associated with the current alternative forms of management.

4.1.0 Material-related Hazards

Material-related hazards include the lack of sterility, toxicity, and biodegradation of the device. The device will be packaged and sterilized by exposure to ethylene oxide (see appendix H). The stent-grafts will be opened in the operating room under the same conditions of sterility used for routine surgical procedures. The stents are made from T-304 stainless steel and there are no likely biocompatibility issues related to the stent. The graft material is twill woven from Micrel polyester yarn by Vasutec (Glasgow, UK). A gel-coated version of this fabric is approved for use as an arterial substitute in conventional surgery.

4.1.1 Deployment-related Hazards

The complications considered to be insertion-related hazards are those that occur during the insertion procedure. Previous clinical experience has provided extensive information on the incidence, avoidance, treatment, and consequences of many of these hazards^{1,2,9,10}.

4.1.1.1 Failure to traverse the iliac arteries

There have been no cases in which the delivery system designed in Perth could not be inserted through the iliac arteries. This is likely due to the relatively long tapered shape, and stiffness of the central carrier. The gradient stiffness of the nose of the device greatly facilitates insertion through tortuous iliacs. The soft, flexible end of the tip follows a guidewire around almost any bend, and in so doing, exerts force on the next segment of the tip to pass into the bend in the artery. This segment is less flexible, but with the help of the

preceding segment, it too can bend. This effect is repeated as the rest of the tip passes through the bend, with the segments becoming progressively more stiff. Eventually, the iliac artery is sufficiently straight to allow the remainder of the central carrier and sheath to pass. The effect of the central carrier stiffness is somewhat counter intuitive. The stiffer central carrier of the Perth system actually facilitates insertion through the tortuous iliac artery by preventing kinking of the sheath.

4.1.1.2 Stent-graft occlusion of the renal arteries

There has never been a case in which the renal arteries were excluded by the proximal end of this stent-graft design. The ability to optimize the graft position following deployment nearly always prevents inadvertent renal artery occlusion. (See Appendix B – Proximal fixation)

4.1.1.3 Proximal stent implanted below the neck of the aneurysm

There has never been a case in which the proximal end of the stent-graft was deployed within the aneurysm sac, likely for the same reasons listed in section 4.1.1.2. Were this to occur, a second stent-graft system could be easily deployed in the appropriate position.

4.1.1.4 Distal stent implanted too high

The modular design of this system allows one to place distal extensions sequentially, thus achieving any desired length. Re-instrumentation of the original stent-graft is quite simple.

4.1.1.5 Early endoleak

In the absence of stent-graft malposition, endoleaks can occur as a result of angulation of the stent relative to the implantation site. This occurs more commonly in the setting of a tortuous aorta. This phenomenon accounts for the 9 percent incidence of endoleaks noted in the preliminary work done with this device². The problem can be avoided by excluding any patient with a very tortuous aorta, or treated by re-orienting the stent following implantation with a cardiac valvuloplasty balloon. The balloon-driven “seating” is now part of the stent-graft implantation protocol.

4.1.1.6 Failure to deploy the stent-graft

The most difficult aspect of modular stent-graft deployment is often catheterization of the short limb. Failure of this step was responsible for the reported instances of failed stent-graft deployment, which occurred in 3 percent of the cases in Perth². All of these cases were among the early experiences of the investigators. Subsequently, a variety of maneuvers have been developed to eliminate this problem. Firstly, the delayed deployment of the proximal (supra-renal) stent permits one to access the short limb while maintaining the capability to reorient the main stent-graft body. Secondly, the long trunk of the stent-graft brings the orifice of the short limb close to the contralateral common iliac artery. Finally, if one is still unable to obtain access to the main stent-graft body through the short limb using the brachial or contralateral femoral arteries, the device can be converted into an aorto-monoiliac device quite easily.

4.1.1.7 Embolism

There have been 5 cases of peripheral embolism using this system. No cases of embolization produced limb-threatening ischemia. One risk factor appears to be the presence of a thrombus lining within the neck of the aneurysm at the proximal implantation site. Numerous investigators have had similar experiences.^{1,3,9} It seems prudent to exclude such patients from consideration for endovascular repair.

4.1.1.8 Systemic effects

The incidence of cardiopulmonary complications following any surgical procedure likely reflects the severity of the preexisting disease and the physiologic stress induced by surgery. The main advantage of an endovascular approach to aneurysm exclusion is the avoidance of the physiologic stress associated with abdominal operation, aortic cross clamping, and prolonged lower extremity ischemia. It is not surprising that endovascular aneurysm repair has been remarkably free of complications such as myocardial infarction, pneumonia, venous thrombosis, and prolonged mechanical ventilation, despite the severe nature of the cardiopulmonary disease in many of these patients⁹. The low complication rate relates to the limited femoral dissection, lower blood loss, and diminished amount of fluid sequestration.

4.1.1.9 Local effects

There were only four cases of wound related complications in the Perth series. This likely relates to the limited access required for the procedure. Additionally, in the absence of graft material in the femoral region, the severity of this complication is markedly decreased.

4.1.2. Performance related hazards

The properly functioning stent graft carries blood freely to the pelvis and legs, and prevents blood from entering the aneurysm cavity. To accomplish this, the stent-graft must have a stenosis free lumen, and the ends of the device must remain securely attached to the arteries proximal and distal to the aneurysm.

4.1.2.1 Proximal stent migration

This complication was seen in approximately 4% of the series described by the Perth group however, all occurred early in their experience. A retrospective analysis has improved our ability to predict which patients will suffer from migration. Looking specifically at the Perth experience, two migrations occurred in patients with an aortic implantation site measuring greater than 28 mm when an undersized stent-graft system was utilized. The third case occurred in a thrombus-lined neck, while the fourth case involved a conically shaped neck.

In addition to the necessary changes in the patient selection criteria, some changes were made to the stent-graft design and implantation methods. The proximal stent is now routinely placed in a supra-renal position. The healthier aortic wall affords better barb penetration and is more resistant to later dilation.

Appendix B contains detailed information regarding the benefits and safety of using supra-renal fixation device and other methods of ensuring aortic attachment.

4.1.2.2 Stent fracture

There have been no cases of stent fracture using the Gianturco Z-stent systems. In this context, the Gianturco stent is defined as a zigzag stainless steel stent manufactured by Cook, Inc., not the devices manufactured by EVT, Guidant, and others.

4.1.2.3 Graft infection

There is only one case of reported stent-graft infection involving *Mycobacterium bovis* in an unusual circumstance. The presumed source of infection in this case was a BCG bladder irrigation for bladder cancer. The organisms were thought to have disseminated systemically, seeded in the spine, and generated in a spinal abscess. This later involved the retroperitoneum and eroded through the aorta.

4.1.2.4 Late endoleaks

Aside from the potential for leakage around the proximal and distal attachment sites, the only potential source of persistent aneurysm perfusion is through patent lumbar vessels or the inferior mesenteric artery^{11,12}. This phenomenon is related to the patient's coagulation status and quality of mural thrombus but largely independent of the type of stent-graft used. The Perth group has seen cases of endoleaks (both early and late) at the same rate as reported by other authors.

4.1.2.5 Ischemic colitis

The stringent restrictions regarding hypogastric patency coupled with the lack of aortic cross clamping has made ischemic colitis a rare complication of endografting. The Perth group reported one of ischemic colitis. Strict guidelines with regard to the preservation of hypogastric patency should minimize this risk.

4.2.0 Protection against risks

Previous clinical and animal experience (in compliance with the Good Laboratory Practice regulations) have been used to achieve the following goals:

- 1) Improve the delivery system
- 2) Develop an adequate insertion and deployment technique
- 3) Determine methods to treat complications
- 4) Improve patient selection

It is hoped that, guided by experience, the above directions will make the endovascular treatment of aortic aneurysms safer and more effective than open surgical repair. Steadily improving results with the Perth group and other suggest this to be the case.

4.3.0 Potential benefits to the subjects and alternative treatments

Although this procedure is being performed world wide for both high and low risk patients, the benefits offered to high risk patients are straight forward. The best method to evaluate these benefits is to compare the potential alternative treatment modalities to that of endovascular repair.

4.3.1 Observation

A patient who is not treated is at risk for aneurysm rupture at an overall rate that depends on the aneurysm's size and the patient's longevity. All patients eligible for inclusion in this study have a high risk of rupture, based primarily on aneurysm size. Once the aneurysm has ruptured, it is usually too late to consider treatment in this patient sub-group as most will die.

4.3.2 Conventional surgery

Conventional repair of abdominal aortic aneurysms is highly effective at preventing aneurysm rupture. However, it is associated with a significant degree of cardiopulmonary complications as a result of a prolonged abdominal operation, significant blood loss and aortic cross clamping. Low risk patients are defined as such because they have enough cardiopulmonary reserve to withstand traditional therapy. Despite the potential for the development of

bowel obstructions, graft infections, occlusions and paraanastomotic aneurysms, the long-term risks of open surgical repair are small. The initial physiologic insult are significant but difficult to quantify. A prospective multi-center review involving 666 aneurysm patients calculated a 15 percent risk of cardiac complications, 8.4 percent risk of pulmonary issues, and 6 percent risk of postoperative renal dysfunction¹³. However, these risks were noted to be both surgeon and institution dependent¹⁴.

4.3.3 Endovascular repair

In theory, endovascular repair minimizes the physiologic stress of surgery by avoiding aortic cross clamping and celiotomy. There is now an increasing body of data to support that assumption¹⁵. The reported lower incidence of reported cardiopulmonary complications noted with endovascular repairs has the potential to significantly benefit patient care^{2,9}. However, concern with this type of repair does not relate to its safety, but its efficacy. There is an accumulating body of evidence to support the assumption that aneurysm exclusion by CT, angiographic or ultrasound criteria indicates freedom from the risk of rupture. Aneurysm rupture following endovascular repair occurs only in the presence of endoleakage¹⁶. Therefore, a patient without evidence of endoleak can be considered effectively treated. However, endoleaks are present in approximately 10 percent of patients following endovascular aneurysm repair. Based on my experience and the experience in Perth, it appears that most of these can be treated by an endovascular approach. A patient with an endoleak is viewed as work in progress.

The long term benefits and risks of endovascular aneurysm repair are less clear. Conventional surgery has few problems, while the long term results of endovascular repairs give cause for concern on many counts. The most serious problem is stent-graft migration leading to late endoleak formation followed by aneurysm rupture. This device has several advantages over any of the other systems being used today. The suprarenal implantation of a barbed proximal stent and balloon-assisted seating is an approach calculated to maximize secure stent attachment. Coupled with stent-graft oversizing and reliable materials this problem is likely dramatically lower in incidence.

5.0 Subject identification, recruitment and consent/assent

5.1.0 Method of subject identification and recruitment

Patients referred for abdominal aortic aneurysm repair will be assessed for acceptability into the study. If they meet the clinical and anatomic criteria, the possibility of an endovascular repair will be discussed in the setting of a scheduled office visit.

5.2.0 Process of consent

The investigator will review the patient's history, physical examination, and radiographic studies prior to obtaining informed consent. A written informed consent form will be obtained from the subject after the purposes of the study, the risks, expected discomforts, and potential benefits have been explained. Patients who speak English poorly will have the opportunity to discuss the procedure with the investigator through a translator. The lack of an appropriate translator will be regarded as a barrier to informed consent, thus resulting in exclusion from the study. Copies of the informed consent will be included in the hospital chart, study records, and the case report form. Another copy will be given to the patient (See Appendix D).

6.0 Internal Review Board

The protocol is currently under evaluation by the Internal Review Board at the Cleveland Clinic Foundation.

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Appendix A

Imaging Protocols

Endovascular aneurysm repair has revolutionized the information required by vascular surgeons to evaluate aneurysms. What was previously described simply as an infrarenal aneurysm is now detailed in terms of neck length and diameter, angulation of the aneurysm with respect to the remainder of the aorta, the extent of distal aneurysmal involvement, and coexisting aortoiliac occlusive disease. Detailed data pertaining to aneurysm morphology are necessary for operative planning and feasibility determination. Vessel tortuosity, the presence, location, and extent of intraluminal thrombus, in addition to any large patent branch vessels arising within the aneurysm sac mandate special consideration. Limitations of current imaging technologies must be recognized in an effort to avoid the temptation to over interpret available data. Furthermore, aneurysm morphology has been noted to be quite dynamic during and following endograft placement. Consequently, physicians frequently strive to predict the behavior of the aorta, stent graft, and iliac vessels; however, this endeavor is met with questionable success.

Imaging technologies available for aneurysm assessment include conventional angiography, spiral CT angiography¹⁻⁸, conventional angiography⁹, magnetic resonance imaging¹⁰⁻¹², and intravascular ultrasound^{13,14}. The advantages and disadvantages of the various methods have been heavily debated, resulting in the lack of a consensus regarding the superiority of a single imaging technique^{9,12,15-17}.

Diameter and length measurements

Ultimately, successful endovascular deployment and long-term aneurysm exclusion are the desired results. It is important to realize that early technical success may not predict adequate long-term outcome. Work at the University of Rochester demonstrated that dilation of the proximal cuff following open surgical repair is associated with preoperative cuff size¹⁸. Statistically, a preoperative neck diameter greater than 28 mm was associated with a more dramatic dilatation over time. Unpublished data from Malmo Sweden, corroborated the phenomenon of the progressive neck dilatation; however, failed to relate this to the preoperative neck measurements. Proximal cuff dilation subsequent to endovascular repair has also been observed¹⁹. Potential flaws in these studies relate to the difficulties encountered when attempting to precisely compare one region of the aorta with concordant regions on follow-up scans. However, it appears prudent to interpret these initial data as potentially significant with regard to fate of the proximal fixation site.

Length measurements calculated from numerical table position recordings, three-dimensional or multiplanar reconstructions of CT, MR, in addition to calibrated angiography have been shown to be of questionable accuracy. Furthermore, aortic deformation brought about by delivery device insertion and the morphologic changes induced by aneurysm exclusion, limit the value of precise preoperative measurements. It appears that angiographic measurements with calibrated catheters provide similar results to measurements obtained from reconstructions of data obtained by CT or MR in a volumetric fashion. It must be understood that although preoperative data may be useful in the determination of the feasibility and sizing of the stent-grafts, it appears unlikely that an exact length measurement will be accurate or necessary for successful aneurysm exclusion. Consequently, a balance must be struck between the benefits obtained from the various advanced, costly and invasive imaging techniques with the benefits provided by each study.

Overall preoperative stent-graft design requires an accurate assessment of the diameter and length of the aneurysm neck, knowledge regarding the relationship between the aneurysm and the renal arteries, iliac dimensions, tortuosity and concomitant occlusive disease. The overall aneurysm morphology, significant angulation, and the quality of the arterial access vessels affect deployment strategies. Standard spiral CT or MR imaging protocols allow axial reconstructions that will provide adequate measurements in the XY plane; however, resolution is on the order of 3 to 5 mm in the Z axis. Consequently, diameter measurements of the aortic neck and iliac vessels are best obtained from axial images. The relationship to the renal arteries is also appreciated using the axial reconstructions. However, tortuosity of the aorta in this region is common and the frequent oval appearance of the aorta likely results from the lack of normality and resultant obliquity. This may cause controversy regarding the true calculation of lumen diameter. We feel that a measurement from the outer margin of the aortic wall to the outer margin of the opposite wall along the shortest axis most accurately estimates aortic diameter. This measurement should be obtained in a progressively distal fashion along three separate images of the aneurysm neck. Additional important characteristics of the aortic neck include the extent of thrombus and atheroma. These are best appreciated following an intravenous contrast bolus. Precontrast images or maximal intensity projections, on the other hand, best delineate aortic and iliac calcifications. Although data are limited with regard to complications directly attributed to the degree of vascular calcification, the incidence of iatrogenic injuries appears to correlate significantly with the degree of vascular calcifications.

Summary

In this light, the measured diameters of the infrarenal neck, common iliacs, external iliacs, and the femoral vessels are best determined by axial images from spiral CT or MR. Angiographic limitations, with regard to the inability to discriminate non-aneurysmal aorta from thrombus lined aneurysmal aorta, relegate this modality to measurements where this differentiation is unimportant. Calculations regarding the length of the neck will also be obtained from axial data. However, larger distances, particularly in the presence of significant tortuosity, will be obtained from calibrated angiographic images, multiplanar or three-dimensional reconstructions from either spiral CT or MR imaging techniques. Thus, the determination of the distance between the lowest renal artery and the aortic bifurcation will utilize one of these measurement techniques. Equivalence between the two imaging modalities has been demonstrated¹², in addition to assessment of accuracy by comparison with surgical findings¹⁷. Furthermore, the distance of the iliac bifurcation from the aortic bifurcation can be determined from any of the aforementioned imaging modalities however, if angiography is used, the measurement extremity contralateral to the catheter insertion site must be approximated.

Comparison of imaging techniques

Controversy regarding the superiority of one measurement technique over the other remains unresolved. Emphasis must be placed on the frequency of morphologic changes noted following endovascular repair. Consequently, although one may desire a precise measurement of stent-graft length, the questionable accuracy of measurement methods coupled with the somewhat unpredictable effect stent-graft deployment will have on aneurysm morphology, lend an aspect of doubt to the desired precision which many have strived to achieve. Notwithstanding, length measurements remain a necessity to define the length of the proximal fixation site and the relative location of bifurcations. Diameter measurements are required to determine the suitability of fixation sites and exclusion of patients that will likely have progressive aortic dilation. A combination of measurement techniques will likely prove complimentary and there is little data to support the superiority of one imaging modality over another. Therefore, this protocol defines the measurements required and the format from which they should be obtained however, the choice of imaging modality remains at the discretion of the physicians involved.

Examples of acceptable imaging protocols:

	CT	MR
Acceptable machines	Spiral capable of >40 seconds	1.5T, Gradients sufficient for single breath acquisitions
Injection volume	150 cc	0.2-0.3 mmol/kg
Injection rate	>2.5 cc/sec	>1 cc/sec
Injection mode	Power	Power or hand
Bolus timing	Test bolus: SmartPrep, C.A.R.E. or equivalent	Test bolus: SmartPrep or equivalent estimated fixed delay
Protocol – precontrast	Low technique diaphragm to proximal femur	Site determined
Protocol – contrast run	Standard	Breath hold 3D gradient echo (GE = efgre3D)
Coverage – start	1 cm superior to celiac axis	At least 256x128x20; >40 cm FOV long axis, supraceliac
Coverage – finish	Profunda femoris origin	Profunda femoris origin
Volume thickness	N/A	Sufficient to include anterior aorta and posterior iliacs
Collimation	<3 mm supra-celiac to 1 cm into aneurysm <5 mm 1cm into aneurysm to profunda femoris	N/A
Reconstruction	2.5 mm throughout – soft algorithm	50% interpolated if support 256-512
Axial DFOV	32 cm	N/A
3D displays	SSD with spine included – 6 projections MIP with spine edited – 6 projections	MIP, include zoom of renal arteries and celiac and SMA origins (sagittal)
Post-injection runs	None	Axial flow sensitive gradient echo parameters to give soft tissue versus plaque contrast slice <5mm
Data submission format / storage	Digital disc, network	Digital disc, network

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Appendix B

Proximal Fixation

Successful endovascular aneurysm exclusion is largely dependent on the adequacy of proximal fixation. Although the replication of the time tested anastomotic suture would be ideal, the technical, mechanical and anatomic constraints imposed by an endovascular approach have resulted in the development of alternative methods to secure graft material to the non-dilated aortic wall. The critical issues remain identical to conventional surgical repair – circumferential apposition, and long-term stability. Although these two principals are closely related, they must be conceptually differentiated to identification of specific mechanical and anatomic factors contributing to the success or failure of aneurysm exclusion.

Graft to wall apposition

The exclusion of the aneurysm is reliant on the prevention of contact between blood flow and the aneurysm sac. Incomplete apposition of graft material to the arterial wall allows a communication between systemic blood flow and the arterial segment one is attempting to exclude. Prevention of this complication requires circumferential apposition of the graft to the arterial wall and is reliant upon appropriately sized devices that exerts a uniform radial force. The total force opposing stent-graft displacement by the circumferential radial force of the individual stents is a function of the cross-sectional forces integrated over the length of the non-dilated aortic neck. Graft material can be pushed against the aortic wall using stents placed within the graft, or conversely, externally positioned stents sutured to the graft material can pull the graft up to the aortic wall. Although the original endografts were placed with balloon-expandable stents¹, self-expanding stents have been shown to be superior with regard to their ability to follow the diameter changes associated with pulsatile blood flow². Currently most of the stent-graft designs under investigation (EVT, Vanguard, AneuRx, Corvita, and Talent) utilize self -expanding stents. Stent placement within the graft material, as opposed to an external design is variable among the devices.

Stent-graft migration

Given the youth of the field of endovascular surgery, no extensive long-term follow-up is available from any investigators. However, concern regarding the durability of this form of aneurysm repair has resulted in meticulous follow-up studies obtained at scheduled post-operative intervals. The continuous forces exerted on implanted devices in conjunction with the strains exerted on the arterial attachment sites will predict the durability of the

procedure. Proximal attachment site failure has been noted to result in a substantial number of migrations and endoleaks during the post-operative follow-up. However, there is a marked variability between centers that is likely dependent upon the rigor of the follow-up imaging protocols, physician planning and deployment of endovascular devices, as well as the structural design of the device itself. Stent-graft migration has been reported to occur in 0-32 percent of the aneurysms treated endoluminally³⁻⁶. The etiology of this migration is likely multifactorial. Contributory factors include post-operative neck dilation, morphologic aortic changes, stent durability and adequacy of proximal fixation. Patient selection and graft over-sizing will impact the extent and effect of proximal neck dilation. The morphologic changes of the aorta are difficult to predict; however, with the exception of progressive aneurysmal dilation, it is unlikely that they will have a detrimental effect on the exclusion of the aneurysm cavity. Proximal fixation mechanisms are likely critical to the stability of the stent-graft position. These can be viewed in terms of the radial forces exerted by the stent against the arterial wall from a cross-sectional perspective, the radial forces exerted over a length of adequate neck, and the quality of the neck itself.

Proximal neck diameter, length and delayed dilation

Unfortunately, aortic morphology following endovascular aneurysm repair is quite dynamic⁷. Two studies have demonstrated the tendency for progressive enlargement of the aortic neck following aneurysm repair. Illig and associates from the University of Rochester noted proximal cuff dilation in one-third of all patients who survived conventional abdominal aneurysm repair⁸. Unpublished work from Malmo, Sweden confirmed this observation⁹. The Rochester group felt that a subset of patients with preoperative aortic diameters greater than 28 mm had a greater tendency to dilate. This was not noted in the study from Malmo. Consequently, in the absence of an anastomotic suturing technique, we reserve endovascular aortic repair for aneurysms with proximal necks less than or equal to 32 mm.

The length of the non-dilated aortic neck allows radial forces imposed by the proximal stents to affect fixation beyond a limited cross-sectional view. Not only does a substantial neck provide additional fixation strength, it confers a measure of security should further aortic dilation occur followed by limited migration. Although there is disagreement among investigators with regard to the minimal infrarenal length required, we have taken a

conservative standpoint and require lengths in excess of 15 mm, despite the additional proximal fixation provided by the suprarenal portion of our device.

Over-sizing

Aside from the issues of the dynamic aortic morphology, measurements obtained by the various modalities (see section on imaging) are used to determine proper stent-graft sizing. Although the quality of imaging techniques has improved dramatically, a measurement error of 10 percent should be expected. The importance of adequate apposition with the arterial wall underscores the need to oversize the stents with regard to measurements obtained from conventional imaging techniques. However, one must also consider the attachment of the graft material to the stent. Extensive over-sizing compared with actual luminal measurements may result in incomplete expansion causing kinks or longitudinal folds in the graft material to accommodate the smaller lumen. These graft defects can allow blood flow access to the aneurysm sac thus creating an endoleak. Furthermore, stents at the proximal fixation site must be placed parallel to the axis of the non-dilated aorta. Thus in extremely tortuous aortas, if the proximal stents cannot be properly aligned with or without the use of adjunctive angioplasty balloons, endovascular repair should be avoided. We prefer to implant stent-grafts with a diameter 10 to 15 percent greater than the measured diameter from CT or MR imaging techniques.

Suprarenal stents

The concept of suprarenal stenting is appealing largely because, this segment of aorta has a lower risk of late dilation, is frequently less diseased in comparison to the infrarenal aorta, and is usually less tortuous than the remaining aortic segments. However, the idea of placing material across the lumen of either renal artery or the superior mesenteric artery has raised concern among investigators. Animal studies in canine and porcine models demonstrated the safety of this aspect of endoluminal stenting¹⁰⁻¹⁴. Renal function and arterial patency were assessed, and noted to be unaffected by stent placement in all studies. Many patients have safely undergone placement of endografts containing suprarenal stents without significant complications¹⁵⁻¹⁷. Although there are multiple potential configurations of supra-renal stents, as long as there are large interstices created with the use of thin wire, it appears that most are fairly equivalent. There have been no cases of renal dysfunction or arterial thrombosis in over 100 patients undergoing endovascular aneurysm exclusion using this particular device in Perth,

Australia¹⁸. Thus, fixation of the stent-graft in the supra-renal aorta will allow close apposition of the graft material to the aorta immediately inferior to the renal arteries, maximization of the length of relatively normal infrarenal aorta exposed to stent-graft radial apposition forces, and stabilize the device in a region of the aorta that is unlikely to experience delayed dilation or have significant vascular disease.

Aortic Barbs

Aside from incorporation of the uncovered stent by a layer of endothelium, the radial forces generated by individual stents combined with the columnar strength transferring stability from distal attachment sites provides the majority of endograft stabilization. The formation of intraluminal pressure ulcers and perforation of the vessel wall limit the degree of acceptable radial strength¹⁹. Consequently, progressive arterial dilation or failure of proximal stents will place the endograft at risk for migration, thus placing the patient at risk for aneurysm rupture. Prior stent designs are centered on the treatment of occlusive disease. The anchoring of graft material within the artery in conjunction with long-term stability of the stent position in dilated arteries are fundamentally different objective, and thus involve alternative structural concerns. The global objective is to maintain the position of the endograft despite opposing forces. Laboratory evaluation of multiple stent types has been conducted. The first study tested the fixation strength of five different stents types. Although there were significant differences, the animal model involved a healthy porcine aorta²⁰. However, this model is not representative of the diseased human aorta present in the majority of patients with infrarenal aortic aneurysms. Currently, most stent-graft undergoing evaluation do not have hooks or barbs^{6,21-23}. The EVT device²⁴ utilized small hooks and developed problems with breakage of the hooks, followed occasionally by stent-graft migration. A simple study, yet unpublished, demonstrated that the use of sizable barbs, in the absence of hooks, dramatically increases the force required to dislodge a stent graft once properly deployed²⁵. Dislodgment occurred by two different mechanisms: distortion of the barbs in an upward direction, or intimal tearing. However, it was apparent that significant strength was conferred to the stent-graft once the barbs penetrated beyond the intima, into the media. Stent-grafts without medial penetration had displacement forces between 1-3 Newtons, while those with medial penetration of barbs required forces in excess of 30 Newtons. Although the risk of penetration into periaortic structures is present, the structural design of the barbs, and specific angulations imposed make this occurrence nearly impossible. No complications attributable to the barbs have been reported to date.

Summary

Proximal fixation remains one of the most important aspects of successful endovascular aneurysm repair. Prudent patient selection is of utmost importance. Aortic neck diameters should be 32 mm or less. A minimal length of non-dilated aorta of 15 mm is required. Stent-grafts will be over-sized by 10 to 15 percent, based on cross-sectional images obtained from CT or MR scans. Supra-renal stenting the addition of barbs that penetrate into the aortic media are both safe, and will increase the forces required to displace the stent-graft.

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Appendix C

Distal Fixation

Although the adequacy of distal fixation is not viewed with equivalent importance to that of proximal fixation, it remains a critical issue in the provision of stent-graft stability and the long-term success of endovascular grafting. The creation of a stable distal seal to prevent an endoleak is essential to aneurysm exclusion. This is largely accomplished with the radial force of a stent opposing the graft material tightly against the vessel wall in a circumferential fashion. When this occurs, depending on the columnar strength of the stent-graft, longitudinal support is conferred to the proximal fixation site. Consequently, careful assessment of the iliac artery will define an optimal site for distal fixation. The adequacy of distal fixation helps to ensure aneurysm exclusion, and assists with proximal fixation. Ideally, distal fixation will occur in arteries that are unlikely to enlarge over time and is not aneurysmal, thus eliminating any risk of rupture. The location of the fixation site along the iliac artery is dependent on the size of the iliac artery, degree of occlusive disease, and location of the hypogastric arteries. Each of these factors must be considered independently, and then in the context of the entire endovascular repair.

Maximal iliac artery size

Despite the fact that iliac aneurysms are most commonly encountered in conjunction with aortic aneurysms, data regarding the natural history of these aneurysms are scarce. Unfortunately, the elegant size-rupture relationship that has been defined for aortic aneurysms has not been described for iliac artery aneurysms. The natural history of isolated iliac aneurysms has been described¹⁻⁵, however, this information must be viewed cautiously when extrapolating from isolated aneurysmal disease to aortoiliac aneurysms. Due to the nature of treatment of abdominal aortic aneurysms, iliac aneurysms greater than 2.5 to 3 cm have routinely been treated simultaneously with the use of a bifurcated graft⁶. Unfortunately, there have been no published series specifically designed to evaluate the natural history of the iliac artery following aortic aneurysm resection.

In summary, there were three series evaluating iliac aneurysms in 50 patients or more. The most recent of which, evaluated 53 patients with isolated iliac artery aneurysms, defined as iliac dilation greater than 3.5 cm⁴. Richardson and Greenfield reported on 55 patients with iliac aneurysms that ranged in size from 2.5 to 18 cm in diameter, with a mean diameter of 5.5 cm. A group of 11 patients did not receive operative treatment, and the aneurysms were followed. Three of the patients were noted to have enlargement of the aneurysm, with rupture occurring in a fourth

patient⁵. McCready and associated reviewed 50 patients with isolated iliac artery aneurysms, defined as arterial dilation greater than 2 cm. Nineteen of these patients were treated non-operatively. Enlargement was noted in 9 aneurysms and rupture occurred in one patient³.

Therefore, although there is some discrepancy in the iliac artery diameter that defines an aneurysm, there have been no reports of rupture in iliac arteries less than 2 cm. The potential for arterial dilation remains ill defined, however, extrapolation from surgical data leads one to the conclusion that iliac diameters less than 2 cm are fairly stable. Consequently, we feel it prudent to avoid placement of distal fixation proximal to any region of the iliac artery measuring greater than 2 cm in diameter.

Hypogastric patency

The internal iliac arteries provide pelvic blood flow and an extensive collateral network to the colon and spinal cord circulation. The relative risks of colon ischemia or paralysis from ligation of the hypogastric vessels are not defined. However, it is clear that surgical ligation of the hypogastric arteries bilaterally increases these risks substantially. The group at the University of Rochester reported on seven patient that underwent elective aneurysm repair with bifurcated grafts that developed spinal cord ischemia. The pelvic circulation was compromised in each case however, when both hypogastric arteries were ligated manifested gluteal and colon ischemia⁷. Similar results were reported from the Henry Ford Hospital⁸ and Northwestern University⁹.

Bowel ischemia resulting from aortic aneurysm surgery carries an extremely grave prognosis. The placement of a bifurcated aortic graft, from an open or endovascular approach, almost always results in the occlusion of the inferior mesenteric artery. In open repairs, the option remains for the surgeon to reimplant the inferior mesenteric artery into the graft material. The treatment of aneurysms with an endovascular approach precludes this treatment.

Consequently, the collateral circulation to the region of bowel supplied by the inferior mesenteric circulation must be preserved if possible. A recent anatomic study from Japan determined that the collateral circulation to the inferior mesenteric bed was dependent on the superior mesenteric circulation in 25 of 28 cases. Two of the remaining cases did not have an adequate collateral circulation; and in one case, the flow was dependent on the

hypogastric circulation¹⁰. Multiple authors have felt it prudent to leave as many of the three collateral beds open as possible, in an effort to avoid colonic ischemia^{7,11,12}.

Extrapolations of these data to direct endovascular treatment are not without fault. Mesenteric hypotension following the placement of an aortic cross-clamping is not encountered during endovascular repair. On the other hand, some feel the embolic risk may be greater in the setting of endovascular repair. There is no question that patients undergoing endovascular aneurysm repair remain at risk for complications arising from compromised pelvic circulation. Reports of colonic ischemia following stent-graft placement have already surfaced¹³. The obvious need to occlude the inferior mesenteric artery without an option for reimplantation, reinforces the need to preserve the hypogastric circulation. We feel it is mandatory to maintain patency of at least one hypogastric artery, and prudent to attempt to preserve both.

Summary

The distal fixation site must measure less than or equal to 20 mm in diameter. One of the hypogastric arteries may be sacrificed preoperatively using standard embolization techniques provided that the other hypogastric is patent and will not be compromised during stent-graft deployment.

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Appendix D

Informed Consent

Endovascular Exclusion of Abdominal Aortic Aneurysms

Patient Consent Form

STATEMENT OF RESEARCH

You are being asked to participate in a research study. The purpose of this document is to provide you with information to consider in deciding whether to participate in this research study. Consent must be based on an understanding of the nature and risks of the treatment, device or procedure. Please ask questions if there is anything you do not understand. Your participation is voluntary and will have no effect on the quality of your medical care if you choose not to participate.

INFORMATION ON THE RESEARCH

You have been asked to consider participating in a clinical research study designed to determine the safety and effectiveness of the Endovascular Prosthesis, an investigational device, used in the treatment of abdominal aortic aneurysms. The Endovascular Prosthesis is a device designed to create a conduit for blood flow therefore bypassing the abdominal aortic aneurysm. The Endovascular Prosthesis is made up of a polyester woven material that is sewn onto a metal web, which self-expands to a predetermined size when placed into the artery. The Endovascular Prosthesis is folded tightly onto a catheter (a flexible, hollow tube) that is inserted into the aorta (large blood vessel in your abdomen) through an artery (blood vessel) in your leg. This Endovascular Prosthesis reinforces the aorta that is weakened by your aneurysm and blood flows through the prosthesis to the arteries that go to your legs. The purpose of this study is to determine whether this Endovascular Prosthesis is safe and effective for the intended use of treating abdominal aortic aneurysms in patients who are at high risk for standard aneurysm surgical repair. The expected duration of the study is approximately two (2) years. Up to 300 patients will be enrolled in this study at up to 1 study site (The Cleveland Clinic).

An abdominal aortic aneurysm is a bulge in the aorta (blood vessels that carry blood from your heart to organs in your abdomen to your legs) caused by a weakening in the artery wall. If left untreated, this bulge may continue to grow larger, and ultimately rupture (break-open), resulting in serious internal bleeding. If you decide to participate in this study, you will be carefully monitored.

Explanation of Procedures

Prior to this investigational procedure, a physical examination will be performed, which will include a medical history and may include ankle-brachial index (blood pressure of your arms and legs). You will have blood tests performed; approximately 2 to 4 tablespoons of blood will be drawn. In addition, diagnostic tests including an angiogram/intravascular ultrasound and a CT scan will also be performed to visualize significant arterial vessels and to obtain important

information regarding the aneurysm. An angiogram uses a catheter (a hollow tube) that is placed into the artery in the groin. A dye that can be seen on x-rays is injected into the catheter into your arteries to see how the blood flows through your aneurysm and the surrounding arteries. Also, the intravascular ultrasound, an imaging catheter to visualize your aneurysm and associated vasculature (blood vessels), will be inserted via the introducer sheath. A CT scan is a special type of x-ray to see the aorta from a different view, in that x-rays are taken to image sections of your abdomen. These sections are very much like the individual slices of a loaf of bread.

The Endovascular Prosthesis procedure will be performed under either regional or general anesthesia. If regional anesthesia is used only a specific region of the body will be insensitive to pain and the nerve impulses from this area will be blocked from reaching the brain. During the procedure you will remain conscious, but may be given a sedative for relaxation. If general anesthesia is used, your entire body including the brain is anesthetized. You will have no awareness of the surgery and feel nothing during the procedure. Your doctor, either the Anesthesiologist or Vascular Surgeon, will discuss with you the type of anesthesia to be used in your procedure.

The procedure for placement of the Endovascular Prosthesis is as follows: An introducer-sheath (small tube) will be placed in your blood vessel (artery) and an angiogram will be performed. Also, the intravascular ultrasound, an imaging catheter to visualize your aneurysm and associated vasculature (blood vessels) will be inserted via the introducer sheath. The Endovascular Prosthesis is introduced into the body through a blood vessel in your arm or leg. This Prosthesis is factory mounted onto a delivery catheter (a flexible tube) which is inserted into the body and guided to the aneurysmal portion of your aorta for placement. The Endovascular Prosthesis self-expands to a predetermined size when placed into the artery. Additional Endovascular Prosthesis may be placed, if required, to assure that the aneurysm is isolated from blood flow. After the delivery catheter is removed, the Endovascular Prosthesis remains in place. In this section of the aorta the blood will flow through the center of the Endovascular Prosthesis. The procedure will be completed by performing diagnostic tests as described above (angiogram & intravascular ultrasound) to visualize the Endovascular Prosthesis and the associated vasculature. The procedure is expected to take about two to three hours and should result in reinforcement of the aorta where the aneurysm is located.

Follow-up Evaluations

As a participant in this clinical study, you will be expected to return for periodic follow-up evaluations so that your doctor can be sure that the Endovascular Prosthesis device is working properly. Prior to discharge from the hospital you will have a physical exam, ankle-brachial index, blood work (approximately 2-4 tablespoons of blood), a CT scan and a KUB (x-ray of the abdomen). Additional follow-up evaluations will be performed at 1 month, 6 months, 1 year and yearly after your treatment. Each visit will include a physical examination, blood work (approximately 2 tablespoons of blood) and you will have a CT scan and KUB. Your doctor may also perform an ankle-brachial index. Each follow-up will require approximately 2 ½ hours of your time.

RISKS AND DISCOMFORTS

The potential risks specific to the use of this investigational device may include, but may not be limited to, the following: bleeding at the site where a catheter was inserted; collection of blood (hematoma) in the tissue at the site where a catheter was inserted; injury to an artery (blood vessel) that may or may not require surgical repair; misplaced Endovascular Prosthesis requiring surgical removal; movement of the Endovascular Prosthesis to an unacceptable place within the blood vessel; ongoing leakage into the aneurysm requiring additional transluminal Endovascular Prosthesis or surgery and death.

Another potential risk to the use of this investigational device is renal failure due to contrast media (dye) received during the Endovascular Prosthesis procedure. The risk of renal failure is not out of the range for routine arteriography (angiogram). The most important predictor of renal failure caused by contrast agents is pre-existing renal disease. Other factors such as age and quantity of agent used are not predictive. The risk can be minimized by preprocedure hydration in patients with renal disease. Consequently, the risk of renal failure is extremely patient variable. Also, renal failure can result from the contrast media you receive from the angiogram performed preoperatively.

In addition, the following complications could be associated with the use of the Endovascular Prosthesis system and/or the procedure necessary to implant the device: respiratory failure; heart attack due to obstruction of one of the major arteries providing blood to the heart; congestive heart failure (inadequate pumping of blood); wound infection at the surface or deep in the tissues where a catheter was inserted; infection of the Endovascular Prosthesis; new abnormal heart rhythm requiring therapy; kidney failure; abnormality of blood clotting that prolongs clotting time; excessive or abnormal bleeding during or after the procedure; obstruction of the intestines due to impairment of their movement; inflammation of the colon due to insufficient blood flow to the colon; insufficient blood flow to the intestines; abnormal blood flow between the aorta and the small intestine; insufficient blood flow to the lower extremities; paralysis of the lower extremities (legs); and reoperation. If any of these complications are discovered in your case, they will be treated appropriately, either with a corrective operation or medical management.

In addition to examinations for routine care, you will be asked to undergo x-ray imaging studies (i.e. CT scan and abdominal x-ray) after placement of the device. These studies will necessitate exposure to a higher level of radiation than you would be exposed to otherwise. None of these imaging tests are done just for the purpose of research; they are all part of routine care for this surgery.

As with any device undergoing clinical investigation, there may be unforeseeable risk to you that are not known at this time. If you are a woman, the procedure may involve unforeseeable risks to you or an embryo or fetus should you become pregnant. It is suggested that pregnancy is avoided and birth control used. If you are unwilling to do this, we ask that you not participate in the study.

BENEFITS

You may not experience any benefits from participation in this study. Potential benefits of Endovascular Prosthesis procedure include, but may not be limited to the following: not having to undergo open surgery; less time under anesthesia and mechanical ventilation (a machine used to assist breathing); less blood transfusions; reduction of the complication that may result from open surgery; reduction in hospitalization and recovery time.

The potential benefits of follow-up procedures and exams are to identify any problems associated with the Endovascular Prosthesis. This information gained from this research may benefit future patients.

ALTERNATIVE PROCEDURES OF TREATMENT

Alternative procedures to the Endovascular Prosthesis system include standard surgical aneurysm repair.

CONFIDENTIALITY

Although every reasonable effort will be made to protect the confidentiality of your records, such protection cannot be guaranteed; agents of the Food and Drug Administration, the Cleveland Clinic Foundation and the Institutional Review Board may inspect and copy the research records if needed. The data from the study may be published; however, you will not be identified by name.

In addition to the above, some of your medical information (such as your CT scans or angiograms) may need to be forwarded to the Endovascular Prosthesis manufacturer, Cook Inc. or Cook Australia, in order to properly size your device. All efforts will be made to keep this information confidential.

RESEARCH-RELATED INJURIES

If physical injury occurs due to your involvement in this research, medical treatment is available, but you or your insurance company must pay the cost of treatment. Compensation for lost wages and/or direct or indirect losses are not available. The Cleveland Clinic Foundation will not voluntarily provide compensation for medical expenses or any other compensation for research-related injuries. Further information about research-related injuries is available from the Office of the Institutional Review Board (216/444-2924).

QUESTIONS ABOUT RESEARCH

If you have any questions about the research or develop a research-related problem, you should contact Roy Greenberg, M.D., of the Department of Vascular Surgery at the Cleveland Clinic Foundation (216/445-5306). During non-business hours, please call 216/444-2200 and have the CCF page operator page Dr. Greenberg or you may reach the vascular surgery fellow on call. If

you have questions about your rights as a research subject, you should contact the Institutional Review Board (216/444-2924).

VOLUNTARY PARTICIPATION

Your participation in this study is voluntary. Your refusal to participate will not prejudice your future treatment or benefits here at The Cleveland Clinic Foundation. You are free to discontinue participation in the study at any time without fear of penalty or loss of medical care. Your physician may terminate your participation in this study without your prior consent if it is in the best interest of your health and welfare. If any significant new findings develop during the course of the study, which may affect your willingness to participate, you will be informed.

COSTS

The Cleveland Clinic Foundation will not pay for any items or services you receive as part of your routine medical care, or as part of this research. You or your insurance carrier will be billed the usual and customary charges for all such items and services. The Cleveland Clinic Foundation will assist you as reasonably as possible in seeking reimbursement for the costs of these items and services from your private or commercial insurance carrier, and will hold you personally responsible for any charges not paid by your insurance plan. You will also be personally responsible for any deductibles or co-insurance related to your insurance plan.

IF YOU DO NOT HAVE INSURANCE, you will be responsible for usual and customary charges as well as for the cost of your device.

IF YOU ARE A MEDICARE BENEFICIARY, The Cleveland Clinic Foundation will follow all program requirements, including the interpretation of available coverage guidelines and the submission of claims. At the present time, we believe that Medicare will cover the costs for all the care you require. If we become aware that Medicare will not pay us for some or all of the charges we now believe to be covered, we will notify you in writing, in advance, if we intend to ask you for payment.

IF YOU ARE A MEDICAID RECIPIENT, The Cleveland Clinic will follow all program requirements, including interpretation of available coverage guidelines and submission of claims. In accordance with our obligations under such Programs, we will seek information regarding your Medicaid coverage for these items and services, and will bill Medicaid accordingly. Any items and services that are not reimbursed by Medicaid will be provided to you without charge.

SIGNATURE

I have read the above information and have had all my questions answered to my satisfaction. I understand that my participation is voluntary and that I may stop my participation in the study at any time. Signing this form does not waive any of my legal rights. A copy of this consent will be provided to you. By signing below, I agree to take part in this research study.

Subject Signature: _____ Date: _____

Witness/Person Obtaining Consent Signature: _____ Date: _____

Appendix E

Case Report Form

Appendix F

Endovascular treatment of aortic aneurysm using the Chuter device

CONFIDENTIAL

Endovascular Treatment of Aortic Aneurysm Using the Chuter Device

Timothy A.M. Chuter, M.D., Linda M. Reilly, M.D.,*
Catherine Canto, R.N.,* Roy Gordon, M.D.,† Jessie Jean-Claude, M.D.,*
Susan Wall, M.D.,† and Louis M. Messina, M.D.**

ABSTRACT

This article assesses a system of endovascular aneurysm repair and determines its potential role in the management of abdominal aortic aneurysm (AAA). The prosthesis was a combination of woven polyester fabric and stainless steel Gianturco Z-stents. Straight (aorto-aortic), tapered (aorto-uniiliac), and bifurcated (aorto-biiliac) stent grafts have all evolved, together with the delivery systems, the patient selection criteria, and the method of insertion, since these devices were first introduced in 1991. Currently, 70% of patients are considered to have the anatomic substrate for endovascular aneurysm repair. All stent-graft implantations were performed in the operating room. Preoperative assessment and postoperative follow-up were based mainly on contrast-enhanced CT, which was performed at 3 days, 3 months, 6 months, and 12 months following repair. If the initial CT showed endoleak, CT was repeated at 2 weeks. Persistent leak at 2 weeks was investigated angiographically as the basis for endovascular intervention, following which CT was repeated again. The results of the most recent (US) experience are as follows. Between June 1996 and September 1997, 46 high-risk patients underwent elective endovascular repair of AAA under an FDA protocol. Aorto-uniiliac stent grafts were used in 38 and aorto-aortic stent grafts in the remainder. The operating time was 190 ± 71 min (mean + standard deviation), estimated blood loss was 303 ± 402 ml, and contrast volume was 153 ± 70 ml. The time from operation to resumption of a normal diet was 0.58 ± 0.58 days, to ambulation was 1.17 ± 0.8 days, and to discharge was 3.42 ± 1.51 days. Six patients had an endoleak on the initial CT, but only 1 of these had leakage 1 month after operation. There were no deaths and no conversions to open repair. Endovascular aneurysm repair with this system is safe and effective in the short to medium term.

KEYWORDS: Endovascular; aortic aneurysm; graft; stent

The "Chuter device" is actually a family of related devices. Straight (aorto-aortic), bifurcated (aorto-biiliac), and tapered (aorto-uniiliac) versions have all evolved through several stages since the first animal prototypes were tested in 1991.¹

It is difficult to compare the results with different versions of this system because they were used

under very different circumstances, at different points in the "learning curve," and on different types of patients. Experience with the homemade bifurcated (aorto-biiliac) stent graft² preceded experience with the industry-made bifurcated (aorto-biiliac) stent graft,³ which preceded experience with the homemade aorto-uniiliac stent graft. Indeed, the

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homemade bifurcated stent grafts in this series were the first bifurcated stent grafts of any kind to be used experimentally¹ and clinically.³ For reasons related to the regulatory environment, the bifurcated aorto-biiliac device was most widely used in Europe, whereas the tapered aorto-uniiliac device was most widely used in the United States.

All three stent-graft configurations have a role to play in the management of AAA, and we will describe all three. But the focus of this article will be on the recent American experience, because this group was the most closely studied, and because the European experience has been described in previous reports.^{2,3}

INDICATIONS

Some of these devices have been used to treat embolism from a presumed aortic source, and some to treat thoracic aortic or iliac aneurysm, but the primary indication for stent-graft insertion has always been AAA. The first bifurcated stent-graft implantations³ were performed in good risk patients with long, straight implantation sites, both proximally and distally. Since then, the selection criteria have become steadily more liberal. Under the current criteria, more than 70% of patients are considered to have the anatomic substrate for endovascular repair, and high anesthetic risk is not a contraindication, so long as the life expectancy ex-

ceeds 2 years. Indeed, under our current FDA protocol only *low-risk* patients are excluded.

We currently regard presence of a suitable implantation site between the renal arteries and the aneurysm (a neck) as the only absolute requirement for endovascular repair of AAA. In assessing suitability, several factors are taken into consideration. The ideal candidate has a long (>15 mm), straight, smooth, cylindrical (distal diameter < proximal diameter + 4 mm), narrow (<28 mm), noncalcified neck, with no lining of degenerated atherosclerosis or thrombus. Of course such cases are rare (outside live demonstrations), but none of these cutoffs is absolute and the decision to treat is based on the cumulative effect of all these parameters. For example, a straight, healthy, cylindrical neck can be as short as 10 mm, while a long, cylindrical neck can be angulated by as much as 90 degrees. The most recent series is replete with examples of irregularity (Fig. 1A), calcification (Fig. 1B), and angulation (Fig. 1C) of the neck; in addition to iliac tortuosity and stenosis (Fig. 1D), iliac aneurysm (Fig. 1E), or the presence of a transplant kidney (Fig. 1F). Iliac artery disease rarely excluded patients from endovascular aneurysm repair because most obstacles at the iliac level can be overcome by endovascular means. Failing that, conventional surgical reconstruction of bypass of the iliac arteries can be combined with endovascular repair, assuming the patient is healthy enough to withstand retroperitoneal exposure.⁶

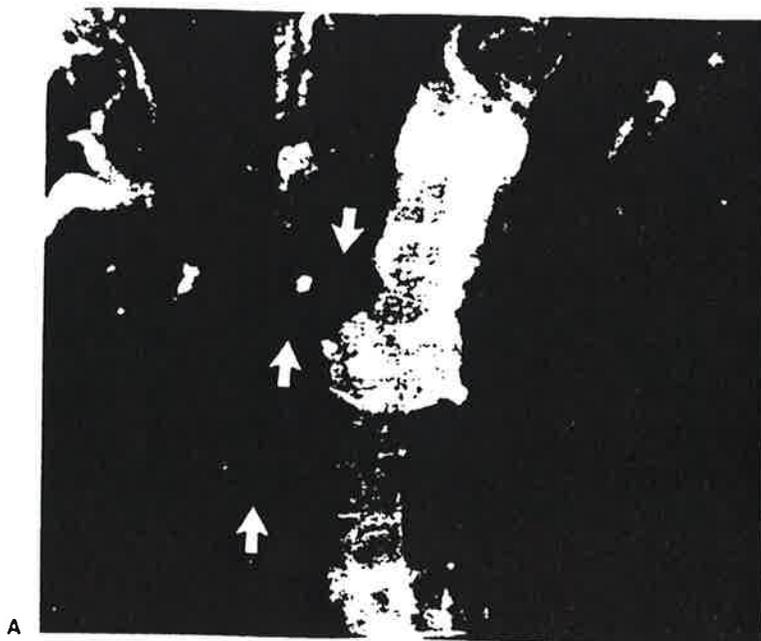
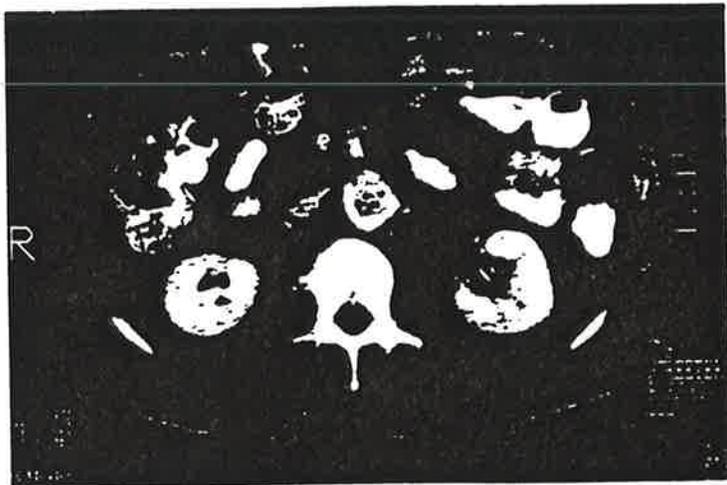


Figure 1. Examples of distorted arterial anatomy in cases of AAA, all successfully treated by endovascular stent-graft implantation. A. Preoperative angiogram, showing an irregular neck and multiple right renal arteries (arrows). (Figure continued on the next page.)

CONFIDENTIAL



B



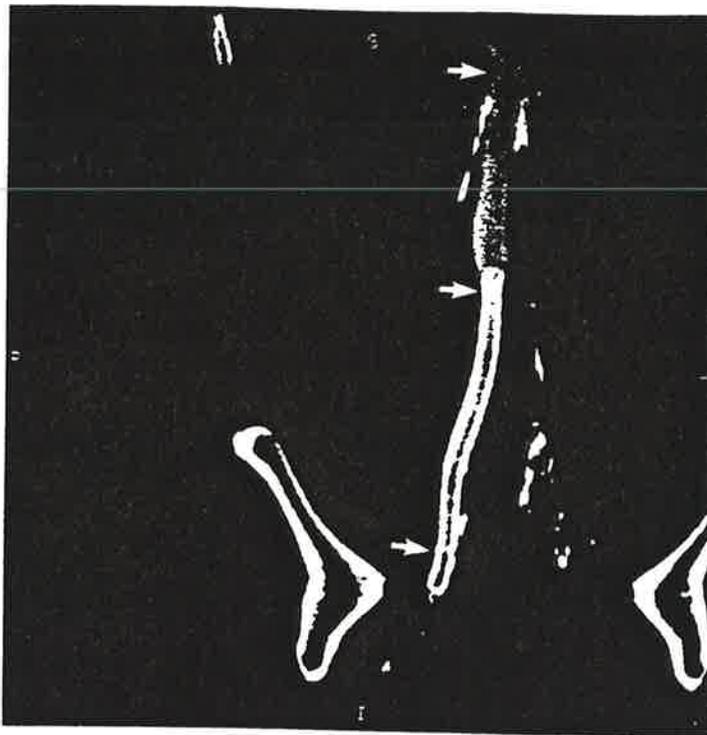
C



D

Figure 1. (Continued) *B.* Preoperative CT, showing a heavily calcified proximal neck. *C.* Preoperative angiogram, showing a short angulated proximal neck. *D.* Preoperative angiogram, showing common iliac aneurysms and diffusely narrowed, tortuous external iliac arteries. (Figure continued on the next page.)

E



F



Figure 1. (Continued) *E.* Preoperative angiogram, showing blood flow to a transplant kidney (arrow) through the right external iliac artery. *F.* Curved planar reconstruction of a postoperative CT, showing the stent graft (arrows) traversing a large right common iliac artery aneurysm.

TECHNIQUE

Some aspects of this system have changed over the years. For the sake of clarity, we will describe only the most recent versions of each device along with the most current technique.

APPARATUS

The basic elements of this system are common to all three stent-graft configurations. The graft attachment mechanism is a self-expanding Gianturco Z-stent, sutured to the inner aspect of each graft orifice. The proximal stent carries caudally oriented barbs; the others do not.

In the loaded delivery system, the lumen of the stent graft is traversed by a central carrier. Surrounding them both is a PTFE sheath, which measures 18 Fr inner diameter and 20.3 Fr outer diameter. Externally controlled locking mechanisms attach the central carrier to the outer end of the sheath and to the upstream end of the stent graft.

The bifurcated (aorto-biliac) stent graft has a single trunk proximally and two limbs distally, each of which is half the diameter of the trunk. The central carrier passes through the trunk and one of the limbs. This limb is held in a compressed state by a small sheath on the central carrier. The other limb is folded on itself, so that when it is initially de-

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ploved the distal end will be in the aneurysm. The end of the folded limb is also constrained by a small sheath and attached to a catheter, which serves to control deployment of that graft limb in the common iliac artery, on the opposite side from the side of insertion. More complete descriptions of the bifurcated system are found in previous reports.^{1,4}

The tapered aorto-uniiliac stent-graft is used in conjunction with a short closed stent graft. This closed stent graft is placed into the common iliac artery on the opposite side from the side of insertion to prevent retrograde flow into the aneurysm.

Whatever the configuration of the primary stent graft, we never begin a case without a supply of short straight stent grafts in a range of aortic and iliac diameters. These serve as proximal and distal extensions in the event that the primary stent graft is inserted too low or found to be short.

STENT-GRAFT INSERTION

The operation is performed in the operating room using a mobile digital imaging system. Straight (aorto-aortic) and bifurcated (aorto-biiliac) stent grafts require open surgical access to only one femoral artery because any necessary instrumentation of the contralateral femoral artery can be accomplished through sheaths. In contrast, tapered (aorto-uniiliac) stent grafts require open surgical access to both femoral arteries because 14 Fr sheaths are used to deliver the contralateral iliac artery occluder and a conventional femoro-femoral bypass is part of the procedure.

Delivery of straight (aorto-aortic) or tapered (aorto-iliac) stent grafts involves: over-the-wire delivery system insertion, sheath withdrawal, stent-graft release, delivery system removal, and completion angiography. In addition, the narrow distal two-thirds of an aorto-iliac stent graft is routinely reinforced with a Wallstent.

Bifurcated (aorto-biiliac) stent-graft insertion has several more stages because one of the limbs needs to reach a point (the contralateral common iliac artery) outside the line of delivery system insertion. First, an angiographic catheter is inserted into the proximal abdominal aorta through a 5 Fr sheath from the contralateral common femoral artery. A stiff guidewire is inserted into the descending thoracic aorta through a 9 Fr sheath in the ipsilateral common femoral artery, and a femorofemoral catheter is placed between the ipsilateral 9 Fr sheath and another 9 Fr sheath on the contralateral side. Then the ipsilateral common femoral artery is opened at the puncture site, the delivery system inserted, and the stent graft released with its proximal end immediately below the renal arteries. The catheter on the folded contralateral limb is at-

tached to the cross-femoral catheter, which is used to pull the left limb into the contralateral common iliac artery where it is deployed by removing the small sheath at its distal end. The right limb is deployed by withdrawing its sheath back over the central carrier. To complete the procedure, Wallstents are inserted into both limbs of the graft, and a catheter inserted for completion angiography. A more complete description of this method is found in earlier reports.^{2,3}

Several technical points apply equally to all forms of repair: aorto-aortic, aorto-uniiliac, and aorto-biiliac. First, we no longer use conventional longitudinal groin incisions to expose the femoral arteries. Oblique incisions at the level of the inguinal ligament give excellent exposure of the proximal common femoral artery and distal external iliac artery (if necessary), close more easily, and are less prone to wound infection or necrosis. Second, all the early catheter and guidewire manipulation are performed through sheaths, even when the femoral arteries are already exposed, to minimize the risk of iliac arterial dissection and reduce lower limb ischemic times. Third, the stent graft is routinely oversized by at least 4 mm to allow for errors in measurement, or subsequent implantation-site dilation. Fourth, if the neck of the aneurysm is shorter than 15 mm, an uncovered portion of the stent graft is placed over the renal artery orifices. Otherwise, the stent graft is implanted immediately below the renal arteries, even if the neck is very long. Fifth, Wallstents are routinely used to support the narrower iliac segments of all aorto-iliac stent grafts. Sixth, no patient leaves the operating room with angiographic signs that the perigraft space is still perfused, a problem known as perigraft leak or endoleak.⁵ Any endoleak seen on completion angiography is treated intraoperatively by endovascular means.⁷ For example, a proximal endoleak, caused by malalignment of the proximal stent, is corrected by balloon inflation; a proximal endoleak, resulting from malposition of the proximal stent, is corrected by insertion of a second stent graft; and a distal endoleak, due to undersizing of the stent graft, is also corrected by insertion of a second stent graft.

FOLLOW-UP

The results of endovascular aneurysm repair were assessed routinely by contrast-enhanced CT prior to discharge from the hospital and at 3, 6, and 12 months. Patients with endoleak on the initial CT (primary endoleak) were reevaluated by CT at 2 weeks. Persistent endoleak was further studied by contrast angiography prior to endovascular inter-

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RESULTS

We only consider endovascular repair a failure if the aneurysm ruptures, or the patient dies in the perioperative period (30 days), undergoes open surgical repair, or has signs of endoleak on contrast-enhanced CT. This definition of overall success includes the patients in whom repair was always successful (continuing success), and those in whom an endoleak resolved or was treated by endovascular means (secondary success), as described in the SVS/ISCVS Reporting Standards for Infrarenal Endovascular Abdominal Aortic Aneurysm Repair.⁹

EUROPEAN EXPERIENCE WITH BIFURCATED STENT GRAFTS

By these criteria, endovascular aneurysm repair was considered successful in 50% of the first 20 cases performed with bifurcated grafts, 75% of the next 20, and 100% of the last 17. The most common cause of failure was graft thrombosis in the first group and stent-graft migration in the second group. The technical modifications responsible for the elimination of these complications are described among the general comments on technique previously listed. Another factor in the high success rate achieved in the last group may have been the inclusion of results with the industry-made device. The thin-walled graft used in the industrial device proved to have significant advantages.

SAN FRANCISCO EXPERIENCE WITH STRAIGHT AORTO-AORTIC AND TAPERED AORTO-UNILIAC STENTGRAFTS

Eighty high-risk patients with large aneurysms have been assessed by CT and catheter angiography since this program's inception in July 1996. Endovascular repair was thought to be feasible in 54 (70%). Forty-six of these have been treated electively, and another 4 on an urgent basis. The results in the 46 cases of elective endovascular aneurysm repair were as follows. There were no deaths and no conversions to open operation. The operating time was 190 ± 71 min (mean \pm standard deviation), estimated blood loss was 303 ± 402 ml, and contrast volume was 153 ± 70 ml. The time from operation to resumption of a normal diet was 0.58 ± 0.58 days, to ambulation was 1.17 ± 0.8 days, and to discharge was 3.42 ± 1.51 days. Most of the complications were related to the open surgical aspects of the case. Hematoma requiring reoperation occurred in 3 patients, seroma in 1, wound necrosis in 3, and wound infection in 2. One patient suffered a non-Q-wave MI without significant sequelae. Another patient had self-limited signs of digital embolism.

Endoleak was present on the initial CT in 6 patients (Table 1). One of these had no signs of en-

Table 1. Early Outcome Following Endovascular Aneurysm Repair

	2 Days (n = 46)	2 Weeks (n = 43)	1 Month (n = 42)
Death	0 (0%)	0 (0%)	0 (0%)
Conversion	0 (0%)	0 (0%)	0 (0%)
Active endoleak	6 (13%)	4 (9.3%)	1 (2.4%)
Overall success	46 (87%)	40 (90.7%)	41 (97.6%)

doleak at 2 weeks, another is awaiting 2 week CT. The other 4 cases had persistent endoleak on the 2-week repeat CT, which was investigated by catheter angiography. One patient, the one with the largest endoleak, had coil embolization to occlude the lumbar arterial outflow, and additional stent-graft placement to occlude the proximal perigraft inflow. Two others had a small endoleak, which was not present on CT another 2 weeks later. In the sole case with signs of leakage at 1 month, the collection of perigraft contrast was remote from both ends of the stent graft, and was presumed to be reaching the aneurysm through lumbar collaterals. This patient's poor renal function tempered our otherwise aggressive approach to the evaluation and treatment of endoleak.

DISCUSSION

As a whole, the combined experience with all versions of the Chuter device shows a steady improvement over the 4 years since this system was first used, even while patient selection became more inclusive, in terms of both arterial anatomy and anesthetic risk. The results with particular stent-graft configurations show the same trend. This ascent up the learning curve reflects the lessons of experience, and the resulting changes in patient selection, insertion technique, and device design. In the most recent series, consisting of 14 high-risk patients, there were no deaths, no conversions to open surgery, and only one case of persistent endoleak, giving an overall success rate at 1 month of 97.5%. The technique is clearly safe and effective, at least in the short to medium term.

The method seems to be versatile, since 70% of cases had the anatomic substrate for successful endovascular repair. Some of this can be attributed to the intrinsic versatility of the tapered (aorto-iliac) stent graft, which allows a choice as to the side of insertion and distal implantation.¹⁰ Of course, the Achilles heel of this approach is the need for a femoro-femoral bypass graft, which has a poor record of long-term patency when used to treat arterial occlusive disease.¹¹ The bifurcated (aorto-biiliac) stent graft does not suffer this potential problem.

but the need for bilateral iliac implantation probably places more constraints on patient selection. In suitable patients one can expect high success rates, as evidenced by the most recent experience with this version of the device.^{2,3}

The line between success and failure is not as clear in endovascular AAA repair as it is in conventional repair—hence the use of such terms as “primary success,” “procedural success,”¹² “technical success,” “clinical success,” “continuing success,” and “secondary success,”⁹ to which we would add “overall success,” meaning that the goal of aneurysm exclusion has been achieved by endovascular means. One problem is the reliance on CT-based diagnosis of endoleak as the determinant of success. This is probably valid, but we need to know a great deal more about the relationship between specific CT findings and other outcomes such as aneurysm growth and rupture. Angiography may have a role in better defining the leak site, but it is too insensitive to be used as a basis for the diagnosis. Half (50%) of our patients with CT-demonstrated endoleak had no discernible abnormality on high-quality multiplane angiograms. Others have reported similar findings.¹³

The durability of endovascular repair remains an open question—after all, the first endovascular repairs of any kind were performed less than 7 years ago.¹⁴ More information is needed regarding the long-term fate of the aneurysm, the stent graft, and the implantation sites after endovascular repair before one can determine the proper role for endovascular repair in the management of AAA. Moreover, much of this information must be device specific. Follow-up in patients treated with the Chuter device is approaching 4 years, but changes in the apparatus and the technique undermine the predictive value of this experience as it relates to the current system.

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Appendix G

Bifurcated stent-graft for abdominal aortic aneurysm

ENDOVASCULAR SYMPOSIUM PAPERS

Bifurcated stent-graft for abdominal aortic aneurysm

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The purpose of this study was to examine bifurcated stent-graft implantation for abdominal aortic aneurysm. Fifty-seven patients were treated and followed with serial computed tomography scans for up to 3 years. Patients were allocated to three groups (first 20, second 20, last 17) according to when the repair was performed. Successful treatment is defined as exclusion of the aneurysm from the circulation, based on contrast computed tomography. Success rates in the three groups were 55%, 70% and 100%. Perigraft leak (endoleak) was present on initial assessment in 4/20, 2/20 and 1/17. Two of these aneurysms ruptured early in the postoperative period. Thereafter, leaks were sought and treated aggressively. Kinking and thrombosis occurred in six of the first 20 patients, but did not occur in any of the last 37 patients, in whom the graft limbs were routinely stent-supported throughout. Infrarenal implantation in very a short neck (< 10 mm), or a thrombus-lined neck was associated with proximal stent migration. In conclusion, changes in patient selection and technique have led to a steady rise in the short-term success rate of the stent-grafted implantation. © The International Society for Cardiovascular Surgery

Keywords: abdominal aortic aneurysm, endovascular, stent-graft, perigraft leak, thrombosis

Bifurcated stent-graft insertion was conceived [1] as a way to extend the range of candidates for endovascular abdominal aortic aneurysm repair to include patients who lack a cuff of non-dilated aorta between the aneurysm and the iliac arteries, which is often the case [2].

In this system, the stent-graft is inserted whole (Figure 1). This differs from the modular approach employed by other systems, in which the stent-graft is assembled *in situ* from multiple components. In the 3 years since the first clinical use of a bifurcated endovascular graft [3] the device and technique have undergone a number of modifications [4]. Both the

causes and the effects of these modifications can be seen in the results. This report will focus on the current device, the current technique, and the longer-term effects of endovascular treatment with this system, although some of the conclusions are equally applicable to other stent-graft configurations and other systems.

Patients and methods

Between October 1993 and June 1996, bifurcated stent-grafts were inserted in 57 patients, of whom seven were women. The device and the method of insertion have all been described elsewhere [4, 5]. Therefore, the following description focuses on changes in the system.

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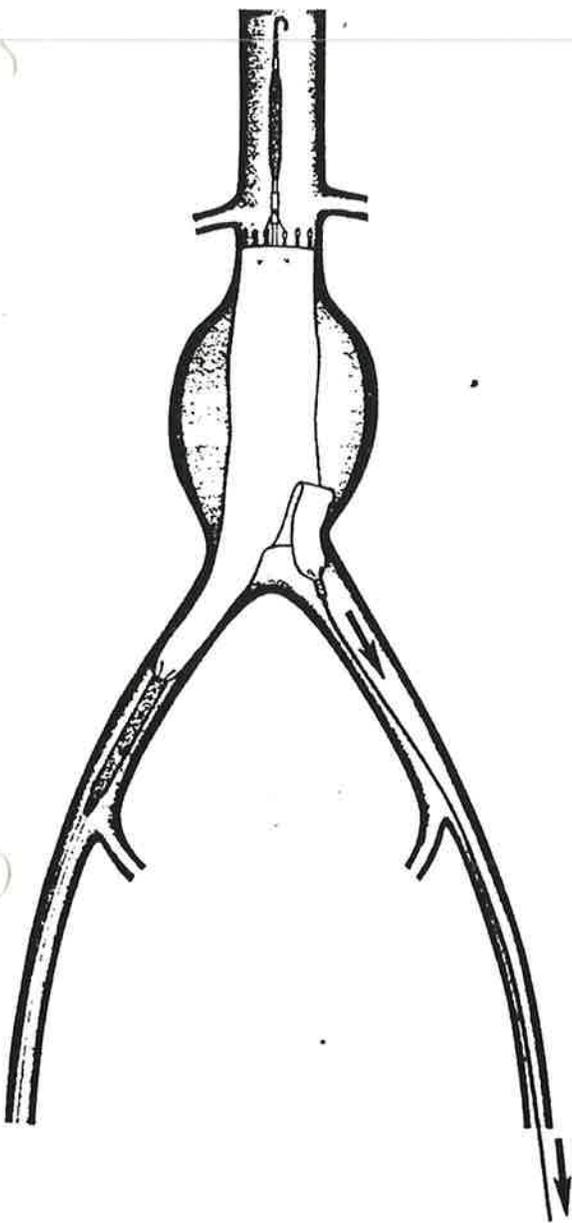


Figure 1 Deployment of the left limb of the graft through traction on the left-limb catheter

Device

The stent-graft consists of a bifurcated graft with three Gianturco Z-stent stents, one at each orifice. The proximal Z-stent protrudes 8 mm beyond the margin of the graft. It has a resting diameter of 10 mm and carries eight caudally directed barbs. The 17-mm distal stents are not barbed. The stent-graft is mounted over a carrier, which passes through the trunk and right limb of the graft. The carrier has a central lumen for a guidewire and release mechanisms for the proximal and distal stents. The stent-graft is compressed around the carrier and loaded

into an 18-Fr (20.3-Fr OD) Teflon primary sheath. In addition to the primary sheath, there are small sheaths for each of the distal stents. The sheath on the left limb is attached to a catheter (the left limb catheter), which runs through the primary sheath alongside the carrier.

The earlier (first 40) stent-grafts were loaded, down-stream end first, into the inner end of the sheath. This caused two problems. First, the barbs had to travel in one direction through the sheath during loading, and in the opposite direction during deployment. Therefore, they had to be short, retractile, and oriented parallel to the long axis to prevent sheath penetration. Indeed, some of the barbs had to be removed altogether, because they continued to penetrate the sheath during loading even after they were bent as flat as possible. The tightly packed conventional graft probably contributed to this effect by pushing the barb tips outward. Second, the orifice of the sheath was always damaged during loading.

The stent-grafts in more recent systems have been loaded from the down-stream end of the sheath. In addition to preserving the smooth profile of the undamaged sheath tip, the new method of loading has permitted the barbs to be angled more aggressively outwards without risk of sheath penetration.

Patient selection

Patient selection criteria became progressively more liberal as the study progressed [4], with the exception of the 10 patients in the industry-sponsored 'feasibility study', which excluded those unfit for conventional surgery and those with more severe distortions of arterial anatomy.

Patients with a proximal implantation site (neck) that is short (< 15 mm length), angulated (>70°), thrombus-lined, wide (>28 mm), conical (widening by >4 mm from one end to the other), or irregular (the diameter or long axis vary) are currently avoided. These values are somewhat flexible and the effects of unfavorable anatomy on an overall assessment of suitability are cumulative. For example, a 10-mm-long neck may be acceptable if it is straight, narrow, and healthy.

Patients in whom the iliac arteries are large (> 16 mm diameter), tortuous (>90° bends), and narrow (< 6 mm) are avoided, especially if the iliac arteries are heavily calcified, or fixed in position by retroperitoneal scarring. The iliac exclusion criteria are even more flexible than the aortic criteria, especially if the patient is healthy enough to tolerate direct surgical exposure of the iliac arteries.

Preoperative imaging

Preoperative imaging was used for patient selection and graft sizing. The protocol varied from center to center, according to the facilities available in each

institution. The work-up also varied from patient to patient, depending on renal function and the findings on initial testing. Patients with borderline anatomy were subject to more extensive imaging.

The basic requirement was either computed tomography or magnetic resonance imaging (MRI), which was supplemented in most cases by catheter angiography. In most institutions, the work-up includes contrast enhanced spiral computed tomography, which is acquired using narrow collimation and low pitch. In most cases this is supplemented by catheter angiography, which is performed in multiple views with a marked catheter for calibration.

Computed tomography data are displayed as two-dimensional trans-axial slices, with a narrow reconstruction interval, or as a series of three-dimensional reconstructions, including Multi-Planar Reconstruction, Curved-Planar Reconstruction, Maximum Intensity Projections in multiple views, or Shaded Surface Displays.

Multi-planar reconstruction of computed tomography data is the most useful source of information. Such reconstructions can be used to assess the distribution of mural thrombus, and make measurements of arterial dimensions. Length determination is sometimes difficult when a tortuous artery occupies multiple planes. These vessels can often be displayed on Curved-planar reconstruction, but this is not a reliable basis for measurements. Under these circumstances, catheter angiography can be used for length determinations. Catheter angiography is also useful to assess the configuration of the neck, and to study the iliac arteries, which can be difficult to assess on computed tomography based images due to calcification and tortuosity.

Graft sizing

In the earlier cases the diameter of the proximal graft was sized to match the diameter of the neck. Oversizing was avoided because the amount of conventional graft material was limited by the size of the delivery system, and because it was thought that the folds in an oversized graft might lead to perigraft leak or luminal impingement. This policy changed as it became possible, through changes in graft construction, for the system to accommodate larger grafts. In addition, oversizing was found to have few if any undesirable effects, whereas undersizing led to migration and leakage.

The limbs of home-made grafts were all 8 mm in diameter, except the distal 15 mm, which was sized to match the diameter of the iliac artery, up to a maximum of 16 mm (Figure 2). The limbs of industry-made grafts were always half the diameter of the trunk of the graft, with no widening distally.

The length of the bifurcated graft was calculated so that the distal end was at least 10 mm short of the internal iliac artery orifice, and at least 20 mm

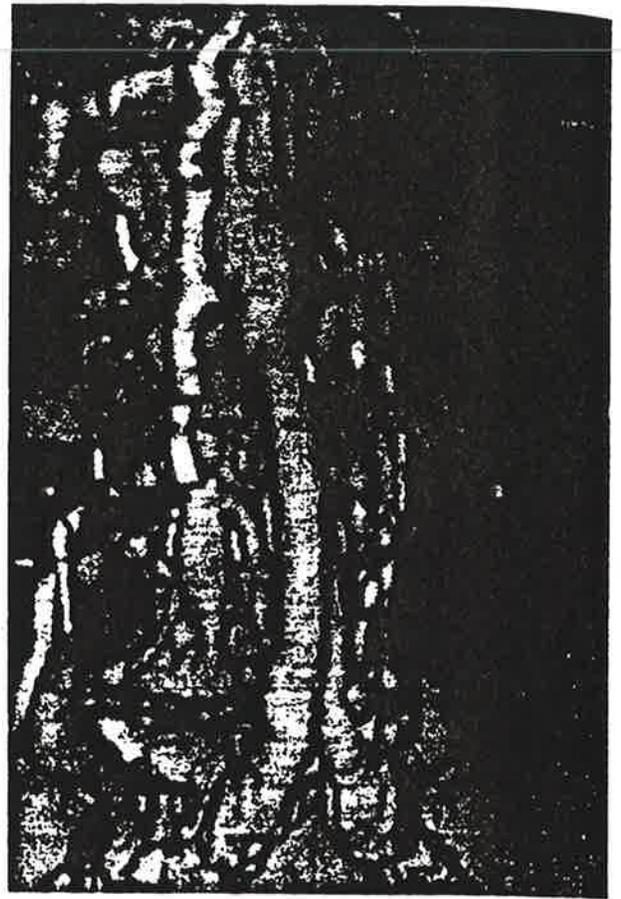


Figure 2 Shaded surface display of spiral computed tomography following endovascular aneurysm repair with a home-made bifurcated stent-graft. Note the narrow (8-mm) graft limbs, which expand into wider 'bell-bottoms' at the distal implantation sites

beyond the bifurcation of the aorta. This was a little more difficult in the industry-made grafts, which were crimped and tended to shorten to a variable degree, especially on the left.

Insertion technique

The primary delivery system is inserted through an arteriotomy in the surgically exposed common femoral or external iliac artery, using an oblique incision directly over the inguinal ligament. Access to the other femoral artery is through percutaneously inserted 8-Fr and 5-Fr sheaths. Cross-femoral catheter insertion, and subsequent left limb catheter manipulations, are performed through the 8-Fr sheath. The 5-Fr sheath is the access point for an angiographic catheter. Even the surgically exposed femoral artery is initially accessed through a sheath to maintain flow through the femoral arteries for as long as possible.

The initial catheter manipulations include: placement of a cross-femoral catheter through the distal arterial tree from one femoral artery to the other,

placement of a left-sided angiographic catheter with its tip at the renal arteries, and placement of a right-sided guidewire with its tip in the descending thoracic aorta.

Once the catheters are in place, the right femoral artery is opened and the delivery system introduced over the guidewire. Proximal stent deployment is guided by angiographic localization of the renal arteries using the left sided angiographic catheter to inject contrast. Sheath withdrawal exposes the left-limb catheter at the groin. The cross-femoral catheter is used to tow the left-limb catheter from the right femoral artery to the left. Further traction pulls the left limb of the graft into the left common iliac artery (Figure 1). The small sheaths are then removed, allowing the distal stents to deploy. The procedure is completed by bilateral Wallstent insertion. Both graft limbs are completely stent supported.

Follow-Up

The exact protocol varied from center to center, but all cases were examined by computed tomography scan prior to discharge from the hospital. Computed tomography was repeated at 6, 12, 24 and 48 months. In addition, some centers performed computed tomography at 3 and 18 months, and some performed routine angiography as part of the follow-up.

Results

The patients are allocated groups 1, 2, and 3, depending on when the insertion procedure was performed. Group 1 includes the first 20 patients, group 2 the next 20, and group 3 the most recent 17. Complications related to the function of the stent-graft are listed in Table 1. Complications of a more general nature are listed in Table 2.

Stent-graft insertion is considered to have failed if the patient dies, the stent-graft has to be removed, or there is perigraft flow on contrast-enhanced computed tomography. These causes of failure are listed in Table 3.

Table 1 Stent-graft-related complications

Complication	Group 1 (n = 20)	Group 2 (n = 20)	Group 3 (n = 17)
Failed insertion	2	1	0
Thrombosis	6	0	0
Aneurysm rupture	1	1	0
Migration	1	4	1
Graft infection	1	0	0

Table 2 Other complications

Complication	Group 1 (n = 20)	Group 2 (n = 20)	Group 3 (n = 17)
Renal failure	1	1	0
Myocardial infarction	1	1	0
Wound infection	1	0	0
Hematoma	0	1	0

Table 3 Criteria of success

Criterion	Group 1 (n = 20)	Group 2 (n = 20)	Group 3 (n = 17)
Initial leak	4	2	1
Current leak	0	1	0
Explant or death	9	5	0
Success	11(55%)	14(70%)	17(100%)

Discussion

All three patient groups show the same trend; the results improved steadily as the series progressed. This is because complications were not random events, but reflected technical errors, limitations of the system, and variations in distal arterial anatomy, all of which proved to be avoidable. Indeed, the 'learning curve' might have been much shorter had the authors early policy of avoiding cases with challenging features such as short neck, angulated neck, and iliac artery aneurysm been continued. Instead, a policy of progressively more liberal patient selection [4] produced an expanding range of potential problems, which had to be solved or avoided before the success rate could continue its upward trend.

Graft thrombosis

The most common complication in group 1 was kinking of the graft limb leading to thrombosis [4]. The uncrimped, woven graft material (Cooley Verisoft) was completely inflexible and buckled easily. In addition, these graft limbs measured only 8 mm in diameter. The completion angiograms obtained in these early cases were often of poor quality. As a result, the extent of kinking was not appreciated until thrombosis occurred, leading to thrombectomy or thrombolysis, followed by a more focused angiographic examination. These kinks could be treated by adjunctive stent (Wallstent) insertion, but the entire limb had to be supported, otherwise angulation localized to the unsupported segment. This led to a policy of routine Wallstent insertion throughout the limbs of the graft, which eliminated the problem. No fully-stented graft limb has ever thrombosed.

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It was initially thought that the crimped thin-walled material used in the industry-made version would not need stent support, because it was capable of bending smoothly. However, kinking was not the only problem. Compression of the graft by narrow segments of the iliac arteries led to indentation and longitudinal folding, which also compromised the lumen. These effects were sometimes hard to see on operating room completion angiography, but they were readily demonstrated by intravascular ultrasound. It seems that bifurcated graft limbs need to be fully stent supported, whatever fabric they are constructed from.

Migration

The most common complication in group 2 was proximal stent migration, which occurred when the stent was implanted beneath the renal arteries in a short neck, or a neck lined with thrombus. Proximal stent migration most often caused late leakage, which was treated in most cases by stent-graft explantation. In one case (group 3), the repair was salvaged by implantation of a proximal stent-graft extension [6].

Stent migration did not complicate the early cases, because difficult necks were initially avoided, and stent migration does not complicate more recent cases, because the current selection criteria exclude patients with conical or thrombus lined necks. Patients with short necks are now treated only if other options are limited by aneurysm size and high anesthetic risk. In these cases an uncovered portion of the proximal stent can be implanted over the renal arteries to enhance anchoring.

Aneurysm rupture

Two patients experienced aneurysm rupture early in the postoperative period [4]. In both cases a large perigraft leak was noted on completion angiography. In addition, both patients were coagulopathic; one from liver disease, the other from coumadin treatment. This experience is reflected in the authors' current policy. Uncorrected coagulopathy is now regarded to be a contraindication to stent-graft implantation, and perigraft leakage on postoperative

computed tomography is now investigated angiographically and treated early. Endovascular methods of treatment [6] are usually successful. It is rare that a case of perigraft leakage is observed in the hope that spontaneous thrombosis will occur.

One exception has been leakage through lumbar collaterals. These tend to occur in patients with little mural thrombus on preoperative computed tomography, possibly indicating some degree of coagulopathy. Following endovascular aneurysm exclusion, blood reaches the lumbar arteries through ascending branches of the internal iliac artery. Percutaneous coil embolization of these collateral pathways is usually effective, but there is often some delay before the perigraft leak ceases altogether [6].

In conclusion, aneurysm exclusion was successful in all recent cases. This not only reflects the performance of the current device, but also the lessons of the earlier experience. Although the short-term success rate is now very high, the ultimate role of this technique will depend on the durability of the repair, and on commercialization of the system, which seems to bear little relation to device performance.

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Paper accepted 25 March 1997

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Appendix H

The Perth bifurcated endovascular graft for intrarenal aortic aneurysm

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The Perth Bifurcated Endovascular Graft for Infrarenal Aortic Aneurysms

G. P. van Schie, F.R.A.C.R.,* K. Siuvarine, F.R.A.C.S., F.R.C.S.E.,†
M. M. D. Lawrence-Brown, F.R.A.C.S.,† and D. Hartley, F.A.I.R.*†

ABSTRACT

This article reviews the characteristics and clinical results of the Perth bifurcated endovascular graft for abdominal aortic aneurysms. Since 1993, 108 bifurcated grafts have been placed in 108 patients. Selection criteria include aneurysms larger than 5 cm in diameter; age greater than 60 years; high risk for conventional surgical repair due to comorbid conditions; proximal neck longer than 1.5 cm; maximum diameter of neck 28 mm. Median follow-up is 18 months (range 1 to 36 months). Primary success was defined as a successfully deployed, patent graft without endoleak at the time of discharge. Primary success was achieved in 94 cases (87%). Failures included 9 acute endoleaks, 3 failed graft deployments, and 2 perioperative deaths. At 6 weeks there were 15 endoleaks, of which 7 were treated percutaneously and 4 have sealed spontaneously. Three cases of graft limb occlusion have occurred, as well as 3 conversions to open repair (1 early, 2 late). Endovascular repair of abdominal aortic aneurysms is feasible.

KEYWORDS: Endovascular graft; bifurcated grafts

The Perth bifurcated endovascular graft (H & LB Endograft, Cook Australia, Brisbane, Australia) for infrarenal aortic aneurysms has been in use since July 1994,^{1,2} evolving in parallel with other similar systems used elsewhere.³⁻⁶ It is based on a Dacron bifurcated graft that is fully supported by self-expanding Z stents. The graft has a long and a short limb, into which is added an extension piece. It is custom made for each patient. Development continues on an ongoing basis, although apart from moving from a partially stented to a fully stented system in the early stages of the program, most developments have been in refinement of the delivery system, which contains some unique features.

DEVICE CHARACTERISTICS^{1,2}

The stent graft is a self-expanding, fully stented bifurcated system, based on a woven non-crimped Dacron graft (thickness: 0.16 mm). Z stents are used throughout, with an uncovered anchor stent at the proximal end with hooks for attachment to the arterial wall. The proximal and distal stents are sewn to the inside of the graft where a seal against the vessel wall is required. The remaining stents are sewn to the outside of the graft, so the inner surface is as smooth as possible (Fig. 1). Stent expansion is augmented by balloon molding throughout, which also helps to embed the stent into the vessel wall.

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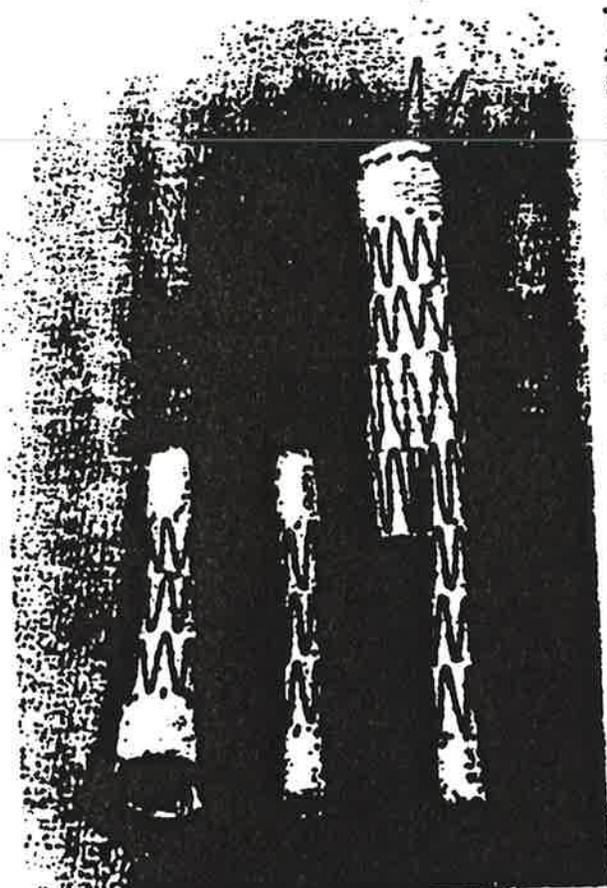


Figure 1. Bifurcated stent graft. Note the hooks on the proximal anchor stent and the potential for tailoring to individual patients.

The graft is mounted on its introducing system with attachments at the top and bottom ends that allow it to be held in tension, moved proximally or distally, or rotated (Fig. 2). These attachments are secured by trigger wires connected to external release mechanisms that prevent accidental release; they only allow release of the distal end of the graft after the proximal end has been deployed (Figs. 3 and 4). The proximal attachment device has a long tapered flexible plastic extension that acts as a vessel dilator and facilitates advancement through tortuous vessels. This proximal attachment is mounted on a metal central cannula that passes over a guidewire. Multiple sideholes allow angiography through the central cannula during deployment. The distal attachment device is mounted on a plastic tube that is coaxial to the guidewire and central cannula and can be moved independently, allowing the graft to be stretched. It can also be locked together with the central cannula enabling the whole device to move as one. The entire mounted device is contained in a coaxial low friction plastic sheath, with a haemostatic valve (Fig. 5). The device can be placed as a one-shot, over the wire system without the need for prior sheath placement. A key feature is that the external sheath can be withdrawn to partly deploy the graft, but the device is still under control, allowing more accurate placement before finally deploying the proximal end. The staged deployment permits some blood flow through the graft, diminishing the risk of thrombosis and preventing distal migration of the device due to aortic pulsation.

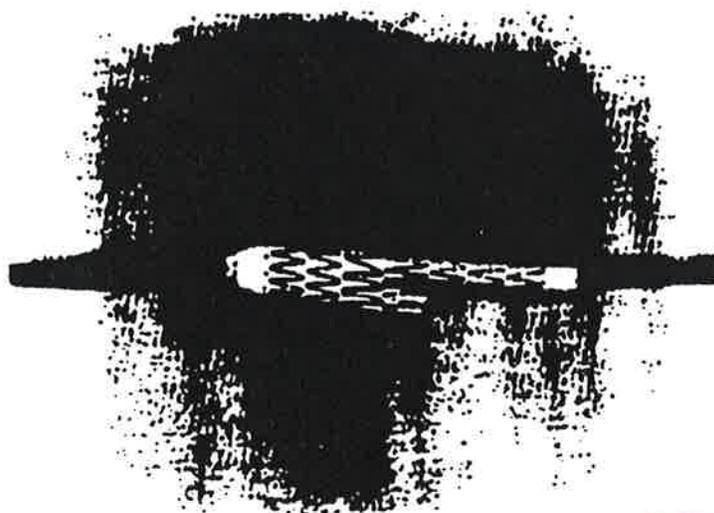


Figure 2. Stent graft mounted on its introducing system; it is partially deployed, but can still be moved or rotated.

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Figure 3. Close-up of proximal attachment showing trigger wire.

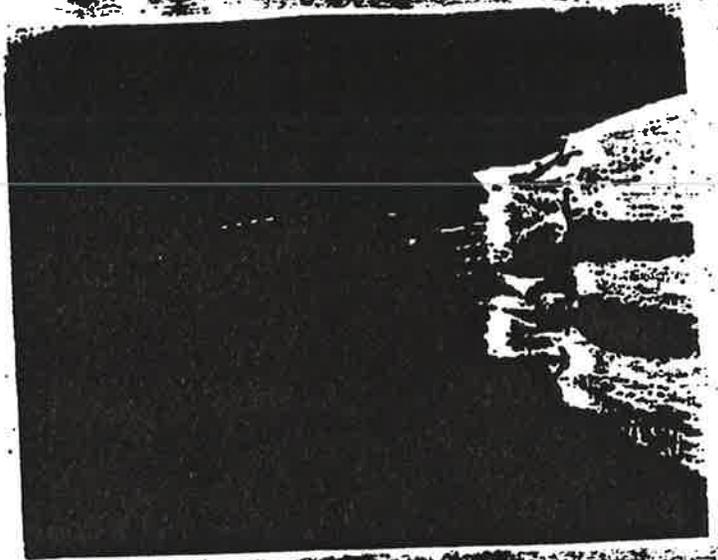


Figure 4. Close-up of distal attachment showing trigger wire.

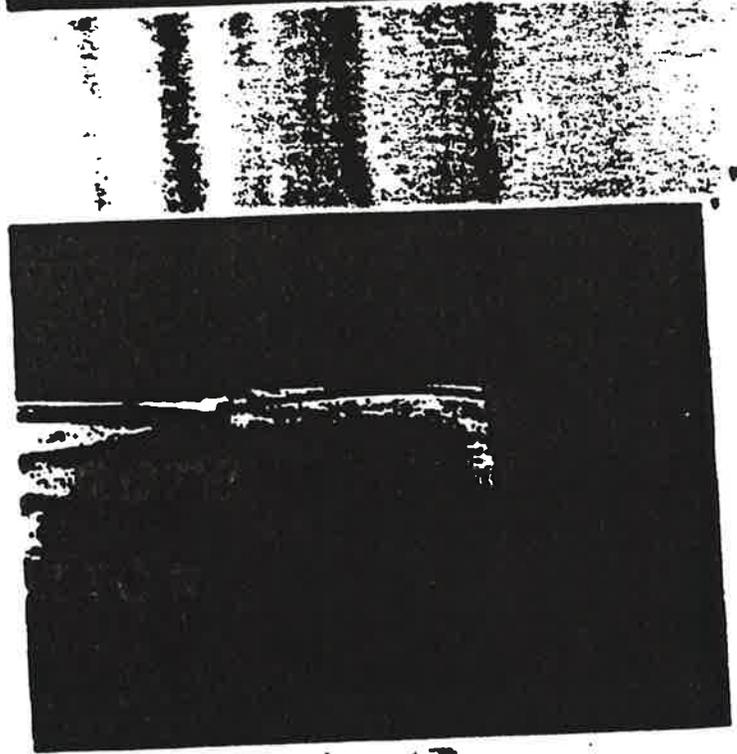


Figure 5. Fully moussed device and extension piece ready for introduction showing sheath and haemostatic valve. Note plastic tube connected to distal attachment (hollow arrow), central cannula connected to proximal attachment (straight arrow), release mechanism for proximal attachment (black curved solid arrow), and release mechanism for distal attachment (white curved solid arrow).



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INDICATIONS AND PATIENT SELECTION

Patients with an infrarenal aneurysm of 50 mm or greater, but for whom open surgery poses a high risk of death or morbidity, are considered for endovascular repair. Table 1 lists the criteria for these patients; frequently they meet more than one criterion. All patients have a helical CT scan; if the aneurysm appears suitable on the basis of this, DSA is performed, with PA and lateral views of the aneurysm, and obliques of the iliac vessels.

The proximal neck of the aneurysm is the most important region of assessment, and at least 10 mm of circumferential contact between graft fabric and normal vessel wall is required for graft fixation. A minimum neck length of 20 mm is preferred, but neck lengths of 15 mm have been sealed successfully. The maximum neck diameter accepted is 28 mm; the system can be tailored to greater diameters, but necks of this size are felt to represent vessels that are diseased and will undergo progressive dilatation. The shape of the neck is also important. A neck of uniform diameter is preferred, but one that tapers distally is an acceptable configuration, as the aortic pulsation produces a downwards force on the graft, "wedging" it in position; conversely a flaring or bell-shaped neck provides inadequate fixation, potentially allowing the graft to migrate distally (Fig. 6). Angulation of the neck, especially in the sagittal plane, is a consideration. Forward angulation of up to 30 degrees from the axis of the suprarenal aorta does not preclude the endovascular technique, but it is taken into account during deployment (see later). Thrombus in the proximal neck interposes between graft and vessel wall preventing fixation, and can be embolized in the process of balloon molding. Calcification is also noted because it is regarded as an indication of a diseased vessel wall.

The configuration of the aortic bifurcation, iliac tortuosity, and calcification are all assessed, especially the angle at which the common iliacs enter the aneurysm sac. A combination of heavy calcification and marked tortuosity is a good predictor of

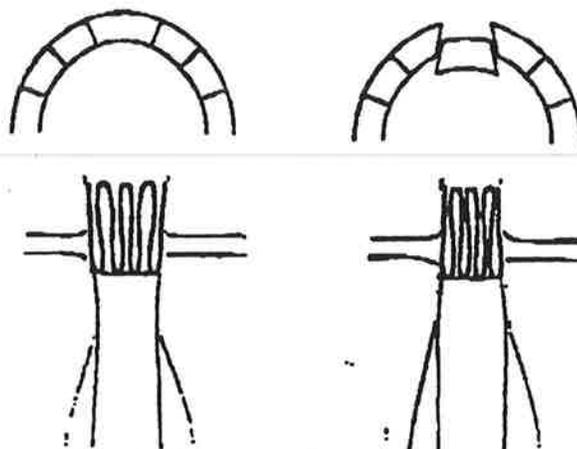


Figure 6. Importance of shape of proximal neck; the "Roman arch principle." A neck that tapers distally is acceptable because the graft will wedge in place. A flaring neck allows distal migration of the graft.

difficulty in passing the device into the aorta. Iliac stenoses are noted and dilated at the time of stent insertion. Other factors noted are renal stenoses and patency of lumbar and inferior mesenteric arteries.

GRAFT CONSTRUCTION

The size of the Dacron graft used is determined by aortic and iliac diameters, usually 24 by 12 mm. At the proximal and distal ends additional tailoring is performed, if necessary, to achieve oversizing by 2 to 4 mm. The length of the body of the graft is kept as long as possible to position the short limb close to the iliac orifice and facilitate easy cannulation as well as increase stability. The lengths and diameters of both limbs of the graft are also tailored to individual patients, allowing good fixation even into ectatic iliac arteries. Small gaps between the stents allow some flexibility and micro length adjustment. Measurements for graft construction are taken from the helical CT data. Full-scale tracings of the 3D-surface rendered images are used to plan stent placement. Curvilinear reconstructions are occasionally used to assess graft length in tortuous aneurysms.

INSERTION AND DEPLOYMENT TECHNIQUE

The procedure takes place in the interventional radiology suite, performed by a team of vascular surgeons and radiologists. Exposure of the common femoral arteries is via a small oblique inci-

Table 1. Criteria for Endovascular Grafting

AAA > 6 cm	Smaller if symptomatic
Age > 80 yr	
Cardiac	IMD, CABG, LV Dysfunction, Arrhythmia
Respiratory	COAD, Lung Function (<50%)
Renal	CRF, Dialysis (Peritoneal)
Gastrointestinal	Portal Hypertension, Cirrhosis, Hepatitis
Hematological	Malignancy, Bleeding Disorders (e.g., thrombocytopenia)
Malignancy	Recent Treatment, Favorable Prognosis
Cerebrovascular	Cerebrovascular accident, Parkinson's
Others	Hostile abdomen, Jehovah's witness, Drugs (e.g., warfarin)

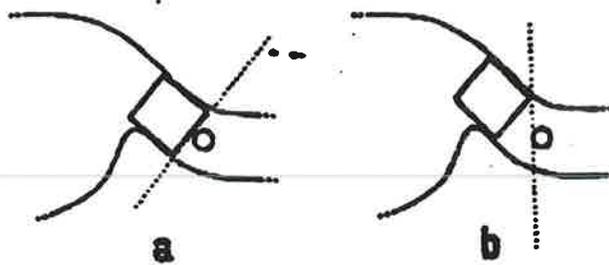


Figure 8. Importance of angling the X-ray beam perpendicular to the long axis of the neck of the aneurysm. In this stylized diagram of a lateral view of a neck that angles forward, the circle represents the renal arteries and the square represents the first covered stent of the device. In situation A the beam (dotted line) is angled perpendicular to the neck. In situation B the beam is not angled and the amount of posterior wall contact is considerably reduced.

ANTICOAGULATION AND ANESTHESIA

A total of 5000 units of Heparin is given, with 3000 units supplied intravenously after the initial angiogram, and approximately 2000 units given in the flushing solutions (1000units/500mls), plus a small amount introduced with the graft. Graft impregnation with Heparin is important, and the graft is pre-soaked in a concentrated solution of 100,000 units/l.

General anesthesia is preferred, but epidural anesthesia has been used in some cases with severe respiratory disease. It has not been necessary with this system to induce hypotension to deploy the graft, nor during inflation of the latex balloon to seat the graft. A central venous catheter is in place in case of sudden adverse bleeding. A urinary catheter monitors urine output and keeps the bladder empty for imaging. Prophylactic antibiotics are administered at the start of the procedure.

Postoperative care takes place in a high dependency unit on the ward, with regular nurse attention for 12 hours. If the patient is well the following day, all lines are removed and normal diet and mobilization commenced.

FOLLOW-UP

Duplex ultrasound is performed on day one to exclude any gross endoleak. If this is suspected, helical CT is performed immediately, otherwise it is performed within 6 weeks. If aneurysm exclusion appears complete, CT scans are performed at 6 months and then annually. A plain abdominal film⁷ is taken at the time of each CT scan to check for stent migration and fracture of any of the metallic components. Creatinine and electrolytes are taken to check renal function.

RESULTS

Since 1993, a total of 136 endoluminal grafts have been placed for aneurysmal disease: 108 of

them have been bifurcated grafts for infrarenal aorto-iliac aneurysmal disease. All the grafts were made in one institution and had similar components. Median follow-up period is 18 months (range 1 to 36 mo.). For the bifurcated system, the operating time and blood loss reduced with experience and improvement in the technique and delivery system (Table 2). Primary success, defined as a technically successfully deployed graft in the correct position and with no occlusion or evidence of endoleak at the time of discharge from hospital, was achieved in 94 cases, giving a primary success rate of 87%. Of the 14 failures, there were 2 deaths: 1 postoperatively and 1 at day 7. There were 3 cases where the graft could not be completely deployed and 9 endoleaks. There were a total of 15 endoleak by 6-week follow-up; the 9 noted initially, 3 associated with failure to deploy, and a further 3 late endoleaks. Of these, 7 were treated by a secondary endovascular technique and 4 sealed spontaneously. Two patients have died of unknown causes but with a persisting endoleak, and 2 small distal leaks persist and are being observed. None of the grafts have occluded, but there have been 3 cases of occlusion of a limb of the graft. One of these was successfully treated with a Palmaz stent, and the other 2 persist untreated. There have been no cases of intraprocedural rupture of an aneurysm. There have been

Table 2. Patient Demographics

Number	108
M:F	91:17
Age (median)	78
(range)	52-89
Size of AAA (cms)	5.5(4.5-10)
Myocardial infarction (%)	22
Angina (%)	32
CABG (%)	10
COAD (%)	23
Diabetic	10
Hypertension (%)	56
CVA (%)	6
Peptic ulcer (%)	22
Renal failure (%)	12

cases of conversion to an open aneurysm repair. One of these was an early conversion and resulted in patient death. Two cases of late conversion to open repair are currently alive.

Ninety-one patients are currently alive. Of the 17 deaths, 12 were of unrelated causes. There were 2 early deaths, and 2 patients who died of unknown causes with a persisting endoleak. One patient died of mesenteric vascular insufficiency attributed to the procedure.

Taking into account the 11 endoleaks that sealed following a secondary procedure or spontaneously, the 5 deaths related to the procedure, the 2 persisting endoleaks, and the 2 persisting limb occlusions, the overall secondary success rate is 90% (97/108).

COMPLICATIONS

General and local complications are outlined in Table 3. The most common general complication was cardiac, with atrial fibrillation as the main arrhythmia needing treatment. The renal failure was transient in all cases except one who needs permanent dialysis because of microemboli to the kidney. Of the local complications, 1 lymphocele needed aspiration drainage on several occasions. Late leaks occurred due to migration of the graft because of continued dilatation of the neck (initial size of neck >28mm, 2 cases), flared neck (1 case), or thrombus lining the neck (1 case). All these cases occurred early in the learning curve, and displayed features that by current criteria would exclude them from an endovascular procedure. Secondary endovascular procedures performed for leaks include a Palmaz stent, two extension pieces, three endovascular conversion procedures from a bifurcate to aorto-uniiliac and crossover graft,⁹ and embolisation of a persistently patent inferior mesenteric artery.¹⁰

Table 3. Complications

Number	108
Blood loss (ml)	100(50-1500)
Length of procedure (hr)	3.5(1.5-8)
MI	0
CCF	4
Arrhythmia	11
Bleed	3
Renal failure	14
Confusion	5
UTI	3
Wound hematoma	5
Wound infection	4
Lymphocele/leak	5
Hematemesis	1
Peripheral emboli	5

Endovascular repair of infrarenal aortic aneurysms using a bifurcated stent graft is a feasible technique that is durable in the medium term and appears promising for the future. The key to success is in thorough preprocedural assessment, identifying factors that would make an aneurysm unsuitable for endovascular repair. There is a steep learning curve, and by continually identifying causes for failure the anatomical indications are rapidly becoming more precise. Delivery systems are also becoming smaller, which should ultimately allow the procedure to be performed percutaneously. As the long-term durability becomes established, the acceptance criteria can be extended to include younger patients, and the present size limitation of 5 cm may also be lowered because of the greater safety of the endovascular technique. This in turn may mean that a greater percentage of aneurysms will meet anatomical criteria.

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Appendix I

Cook manufacturing and labeling device information

Supplier of the Device

COOK INCORPORATED
925 S. Curry Pike
P.O. Box 489
Bloomington, Indiana
Ph: 812-339-2235 or 800-346-2686
Fax: 812-339-5369

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Establishment Registration#1820334

Basic Device Description

The device will be comprised of several components to include:

Z-Stent component materials:	Specification#
--Stainless steel (304) round wire	COOK M.S.#205
--Silver Solder	COOK, #430
--Gold Marker bands	99% purity
Graft component materials:	
--Uncrimped twillweave textured polyester	SULZER MEDICA
Stent/Graft Delivery component tubing materials:	
--Dilator Inner Stainless Steel Cannula	COOK M.S.#206
--Dilator Outer Vinyl Radiopaque Tubing	COOK M.S.#150
--Sheath Tubing	COOK M.S.#126

Performance Testing

Numerous *in vitro* and *in vivo* pre-clinical tests have been done both on the stent/graft device itself as well as the individual components which comprise the device. Detailed test reports and results are being compiled for inclusion in a COOK INCORPORATED Device Master File to be submitted to the U.S. Food and Drug Administration. For this physician-sponsored IDE application, only summary information is being reported with this application.

Mechanical testing for the ZTM-stent component includes Finite Element Analysis (FEA) testing, fatigue/flexural testing, expansion properties, corrosion testing, tensile testing, and biocompatibility testing. Additionally, testing is underway to complete the requirements as specified by the Endovascular Graft Committee, in their Guidelines for the Development and Use of Transluminally Placed Endovascular Prosthetic Grafts in the Arterial System

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The graft material which is used in this device is processed according to the requirements of a commercially available implantable graft material. It is supplied by the graft vendor uncrimped and nonsterile and was cleared for marketing under K964959. Testing of the graft material has included water porosity (permeability), burst strength, kink radius, tensile strength, suture retention, nominal wall thickness, and biofunctionality. Biofunctionality of the graft material was assessed in a canine model and was measured by analysis of healing, patency, macroscopy and morphology, platelet accumulation, and prostaglandin secretion on the luminal surface. In addition, biocompatibility studies have confirmed the material is nontoxic and suitable for use in a medical device. These studies included tissue culture cytotoxicity, delayed contact dermatitis in the guinea pig, intracutaneous reactivity in the rabbit, acute systemic toxicity in the mouse, pyrogenicity in rabbits, hemolysis tests, and muscle implantation.

Likewise, the ZTM-stent has also been extensively tested and is currently commercially available for biliary, tracheobronchial and esophageal indications. It has been in continuous commercial since it was cleared under the following premarket notifications. Please incorporate these files by reference.

Biliary Z TM Stent	Sizes Available -- Expanded diameters of 6mm, 8mm, 10mm, 12mm, and 14mm, in lengths of 1.5cm, 3.0cm, 4.5cm, 6.0cm, 7.5cm, and 9.0cm.
510(k)#K882610	Found S.E. on April 21, 1989
Intended Use:	Used to maintain patency of a bile duct which is obstructed by tumor or fibrosis. The self expanding stent is designed for placement using a percutaneous introducer set. Supplied sterile in peel-open packages. Intended for one-time use.
<hr/>	
Tracheobronchial Z TM -Stent	Sizes Available -- Expanded diameters of 15mm, 20mm, 25mm, 30mm, and 35mm, in lengths of 2.5cm and 5.0cm.
510(k)#K891411	Found S.E. on December 18, 1991
Intended Use:	Used to maintain patency of a stenosed trachea or bronchus due to extrinsic compression, caused by fibrotic stenosis or tumor. It is indicated as a palliative measure particularly for patients with end-stage malignant airway obstructions. It is not intended for intravascular use. The stent is made of stainless steel and is self-expanding. Delivery into the trachea or bronchus is performed orally with the

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appropriately sized Cook-Z™ Stent Introducer Set. Barbs located on the opposing sides of the stent body are designed to prevent migration. Supplied sterile in peel-open packages. Intended for one-time use.

**Esophageal
Z™-Stent**

Sizes Available -- 18mm expanded medial diameter with 25mm proximal and distal expanded diameters, in lengths of 10cm, 12cm, and 14cm.

510(k)#K945201

Found S.E. on January 4, 1995

Intended Use:

Used to maintain patency of the esophagus by transversing esophageal strictures due to tumor encasement or compression. Polyethylene film covering the stent prevents tumor ingrowth. Double flared design and central fixation barbs facilitate stabilization within the esophagus. The inner diameter of the stent is 16 mm enabling the patient to consume well-chewed food. Delivery of the stent is performed using the specially designed introducer supplied with the set. Not intended for vascular use. Supplied sterile in peel-open packages. Intended for one-time use.

Clinical Testing

The clinical application of this device has been previously described in this application.

Labeling

The device will be labeled as an investigational device as shown in the attached draft labeling format. Additional labeling is proposed to include directions for use of the device.

Packaging

The device will be packaged in standard COOK packaging materials which include inner and outer pouches made with clear film and Tyvek paper. These packaging materials are standard use materials and have been shown to provide an appropriate microbial barrier for periods up to, at a minimum, five (5) years. The devices subject of this investigation will be conservatively labeled with an expiration of two years.

Sterilization

The device will be supplied sterile. The method of sterilization is Ethylene Oxide. Sterilization will be performed, monitored and controlled to assure a sterilization assurance level of 10^{-6}

SAMPLE LABELING

INTENDED FOR ONE-TIME USE. STERILE IF PACKAGE IS UNOPENED OR UNDAMAGED.
Federal (U.S.A.) law restricts this device to sale by or on the order of a physician.

REORDER# TFB-1-22

ZENITHTM AAA ENDOSTENT
WITH DELIVERY SYSTEM

ENDOSTENT LENGTH: 102MM
ENDOSTENT DIAMETER: 22MM

LOT NO. SAMPLE

DO NOT USE AFTER 2000/07

RC 994

A Cook Group Company
P.O. Box 489 Bloomington, IN 47402 USA

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CAUTION:

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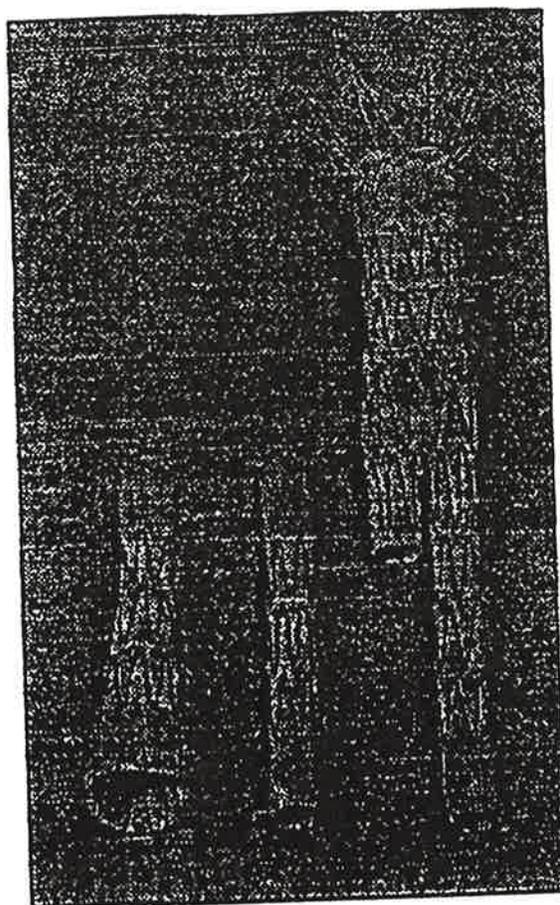
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The Main Graft Component

The prosthesis is of woven dacron, and is fully stented with self expanding stainless steel "Z" stents. These provide stability and the expansile force necessary to open the lumen of the graft during deployment and also the necessary attachment and seal to the vessel wall.

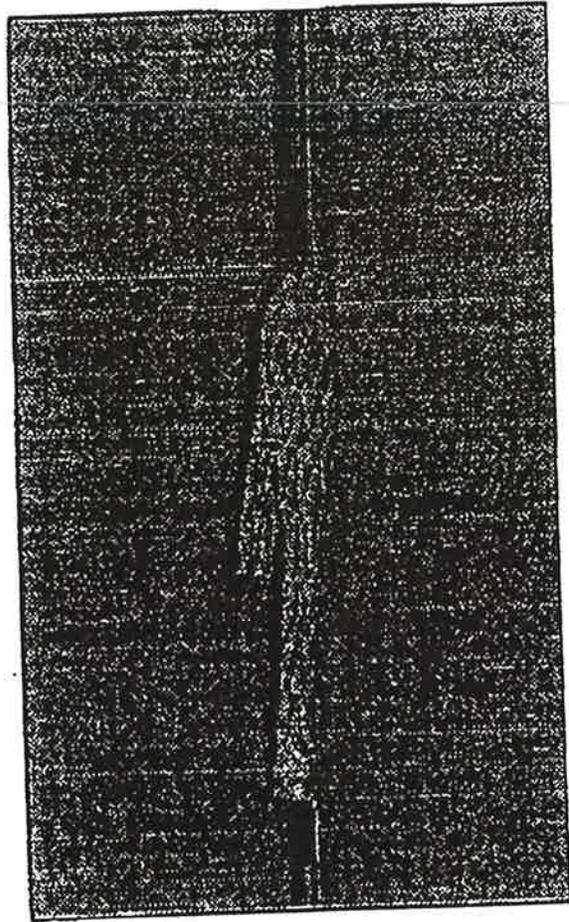


The stents are on the inside of the graft where it is necessary to seal to the vessel or other portion of graft material, and on the outside of the rest of the graft to allow the lumen to be as smooth as possible, and for improved bending characteristics.

There is an uncovered stent at the top end of the graft which features attachment devices for positive location to the vessel wall.

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The device is mounted on a delivery system with the top uncovered Gianturco stent encapsulated in a top cap.



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SAMPLE LABELING

REF

REORDER#

TFB-1-22

ZENITH® AAA BIFURCATED MAIN BODY GRAFT
WITH THE H&L-B ONE-SHOT™ INTRODUCER SYSTEM

PRELOADED BIFURCATED MAIN BODY GRAFT

- AORTIC GRAFT DIAMETER: 22 MM
- ILIAC LEG DIAMETERS : 11 MM
- MAIN BODY LENGTHS:
 - * CONTRALATERAL LIMB: 74 MM
 - * IPSILATERAL LIMB: 104 MM
- DELIVERY SYSTEM: 18 FRENCH

U.S. PATENT NUMBERS: 4,580,568; 5,387,235; 5,456,713; 5,562,726; 5,693,084;
720,776; 5,755,777 OTHER PATENTS PENDING AND GRANTED

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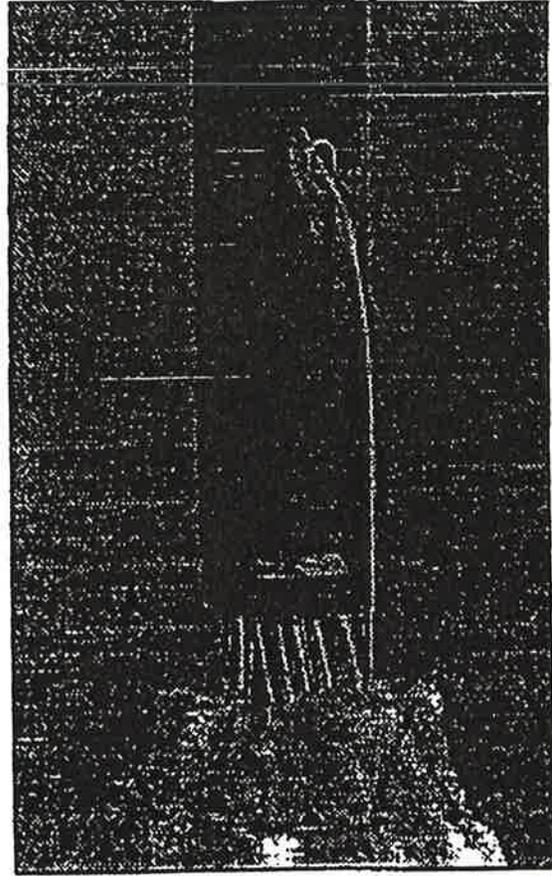
CAUTION

INVESTIGATIONAL DEVICE, LIMITED BY
FEDERAL (U.S.A.) LAW TO INVESTIGATIONAL USE

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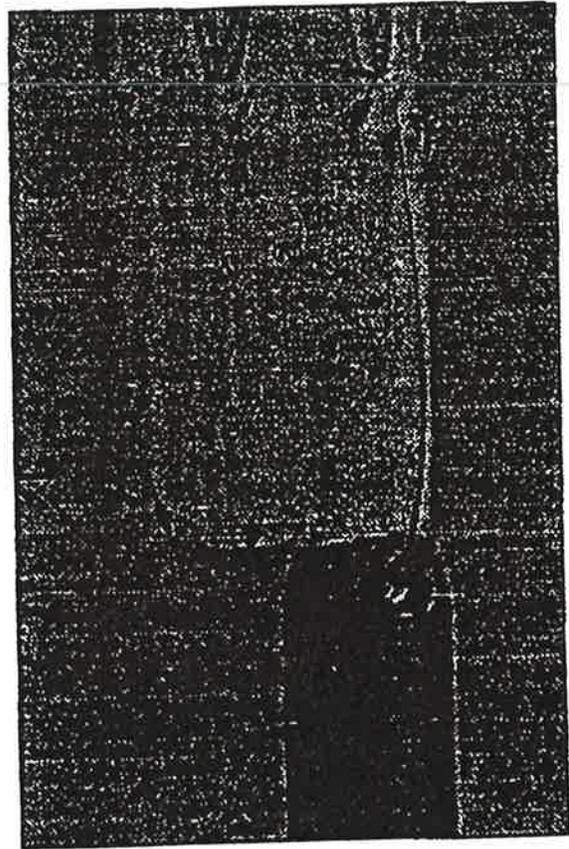
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It is held in place by a trigger wire which is released remotely at the time of deployment.



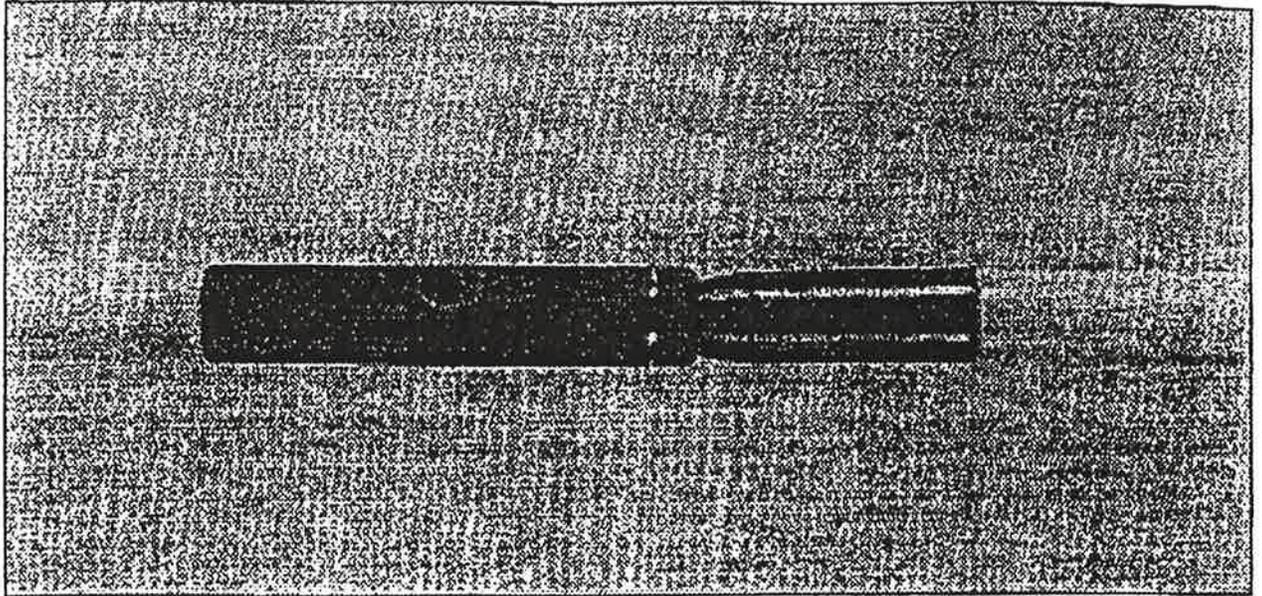
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The bottom end of the graft is also attached to the introducing system and is controlled and released in the same manner.



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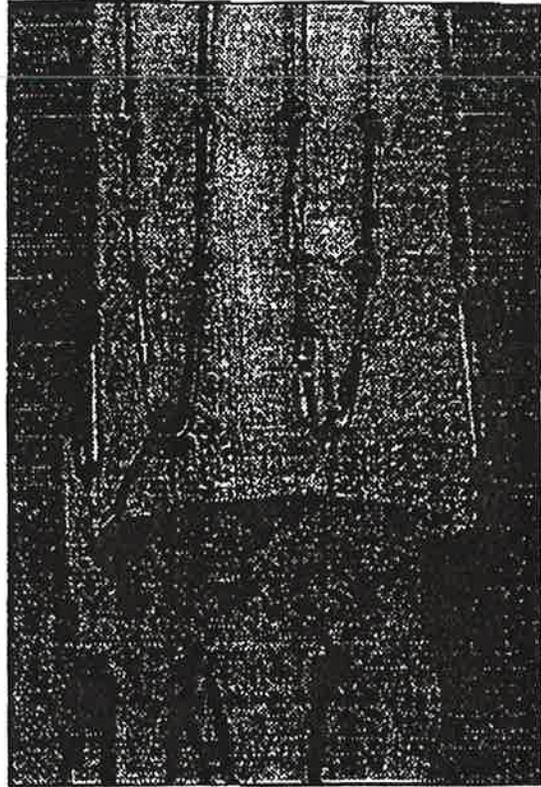
The introducing system also features an extra long flexible tapered tip, for ease of introduction into the artery, and advancement into the aorta. This features side holes into the central lumen of the coaxial combination to allow angiography during phases of deployment.



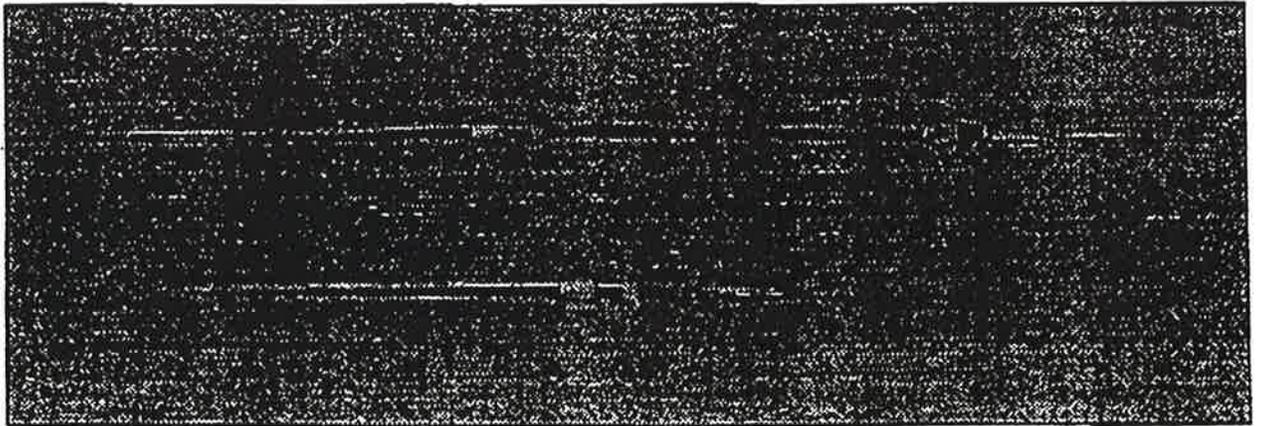
After deployment of the prosthesis the bottom attachment device on the grey tube is advanced over the top cap cannula to dock with the top cap to allow it to be retrieved with less likelihood of catching on stents, graft or the introducing sheath.

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There are radiopaque markers on the most lateral aspect of the short limb to allow orientation.

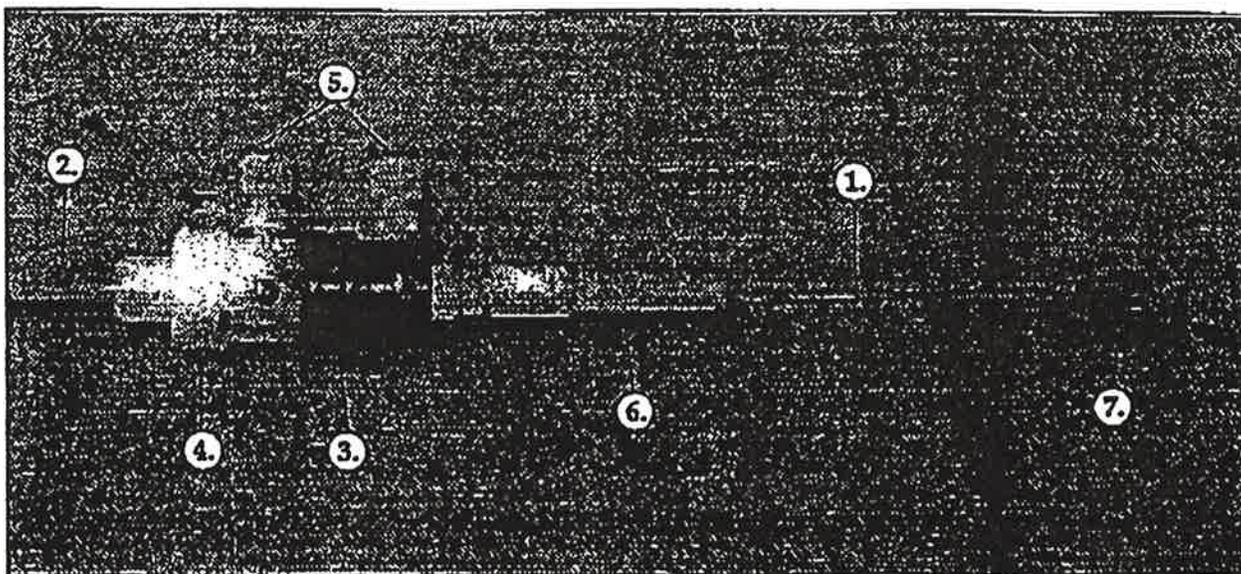


The graft and the devices to which it is attached are contained within a low friction sheath for introduction into the vessels.



External end of introducing system showing :

1. Top cap cannula
2. Grey outer end of coaxial bottom attachment device
3. Black release device for top cap trigger wire
4. White release device for bottom attachment trigger wire.
5. Safety locks for trigger wire release devices.
6. Pin vise that locks grey bottom attachment system to the top cap cannula.
7. Fitting on top cap cannula to allow injections through the side holes proximal to the top cap.



The Extension Leg

The extension leg is also mounted in its own delivery system incorporating a flexible tapered tip, a low friction outer sheath and a "pusher" to locate the graft as the sheath is withdrawn during deployment.

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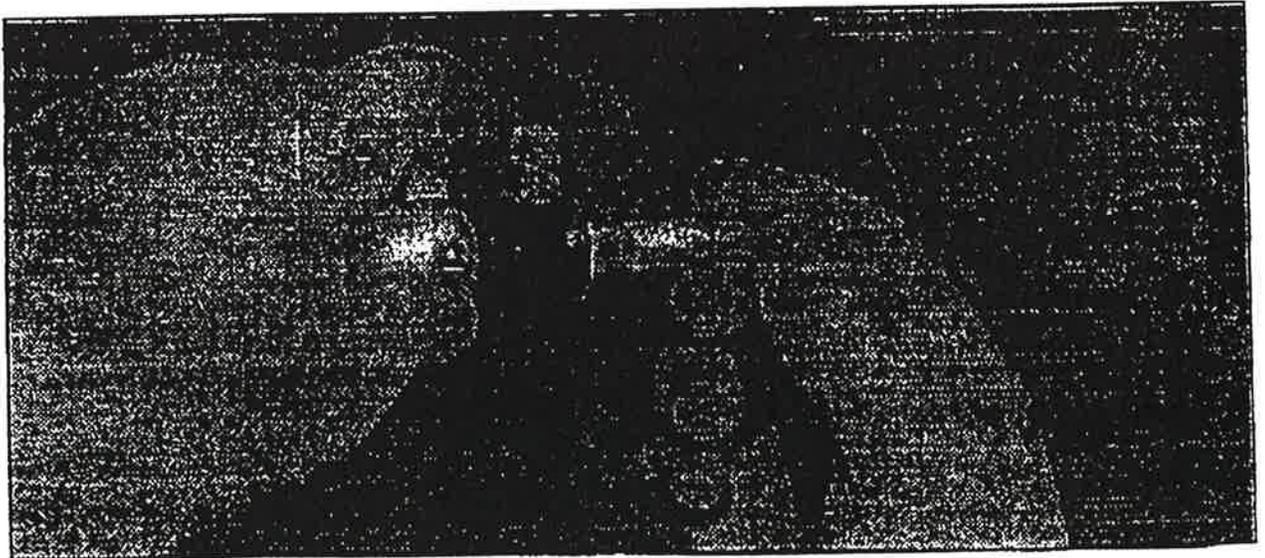
Preparation of
the Graft/Stent
Assemblies

*Preparation of the
Main Graft Assembly*

Strip off the peel-away sheath that protects the haemoreduction valve



Check that the pin vise is tightened on to the top cap cannula



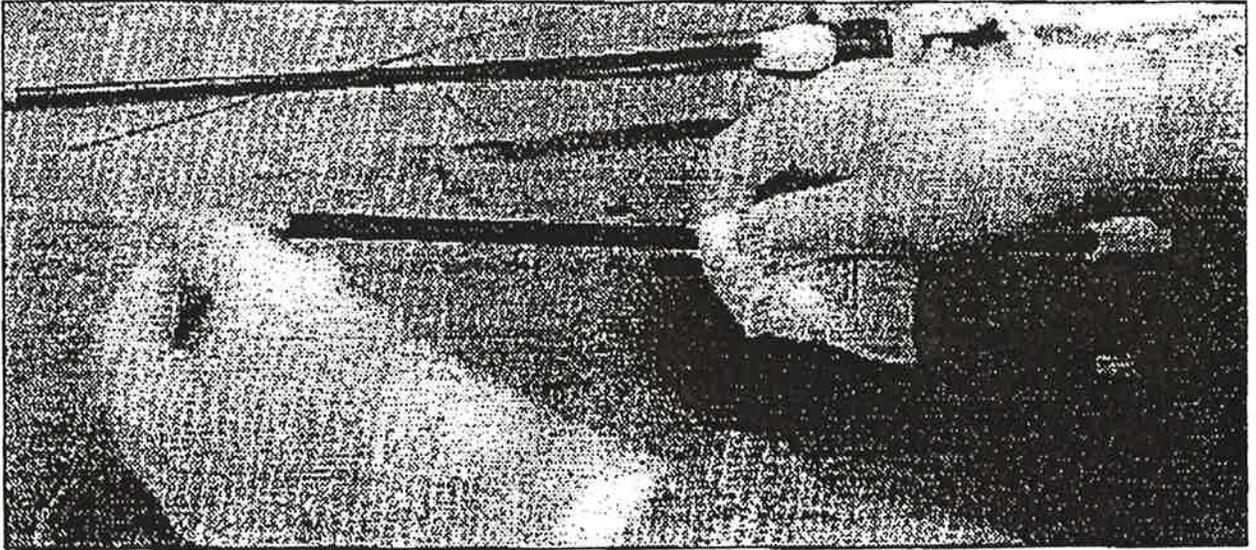
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Apply a thin coating of silicone lubricant to the surface of . . .

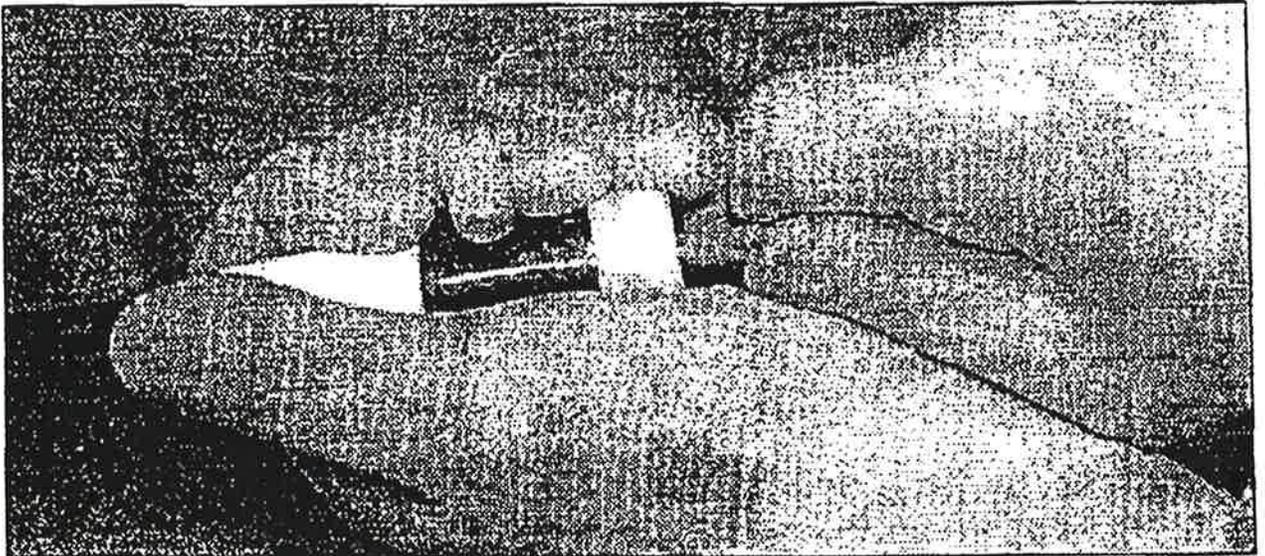
the tapered tip

the black sheath

the grey bottom attachment device

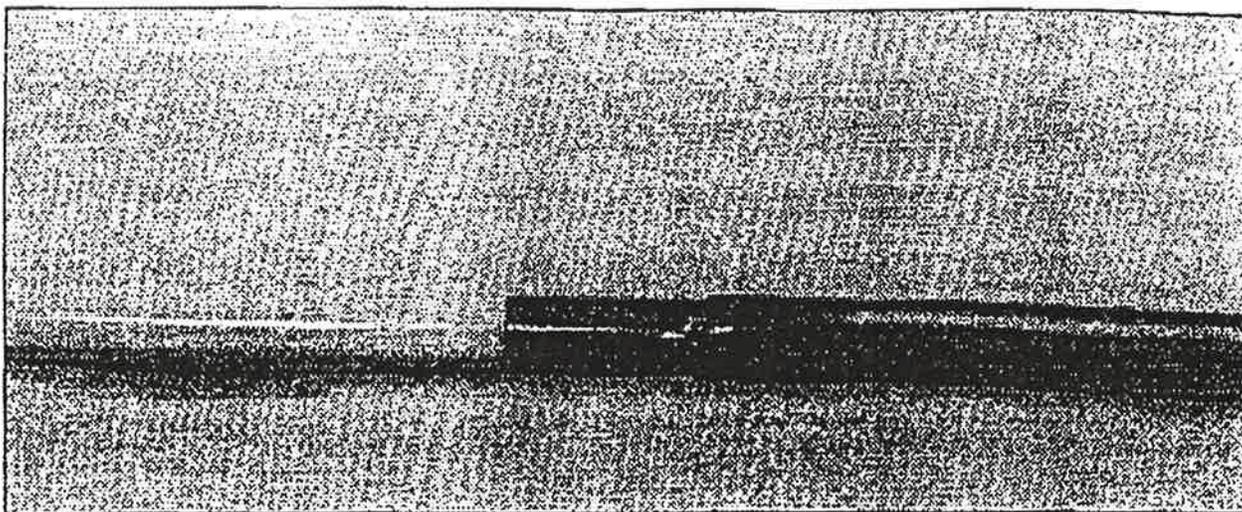


Carefully push the grey bottom tube into the sheath until . . .



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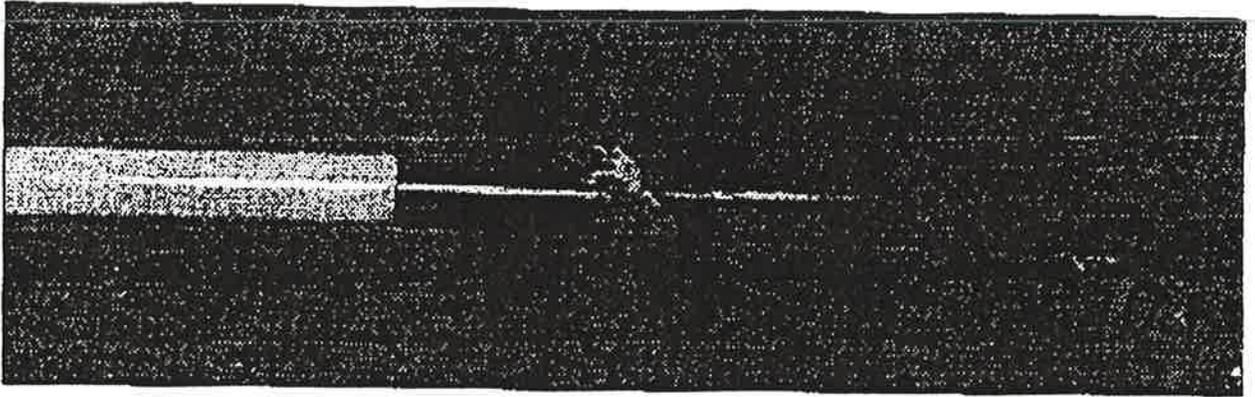
... the trigger wire in the top cap becomes visible. Take care not to push it too far.



Hold the system with the tapered tip uppermost and flush, through the haemoreduction valve fitting with extra strong heparin solution until . . .

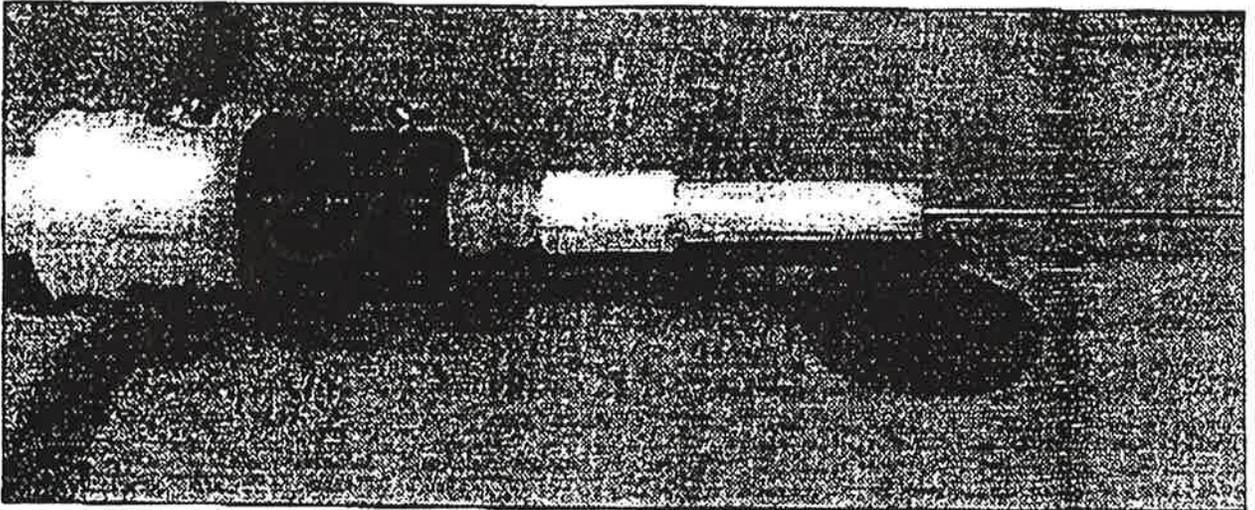


fluid emerges from the top cap.

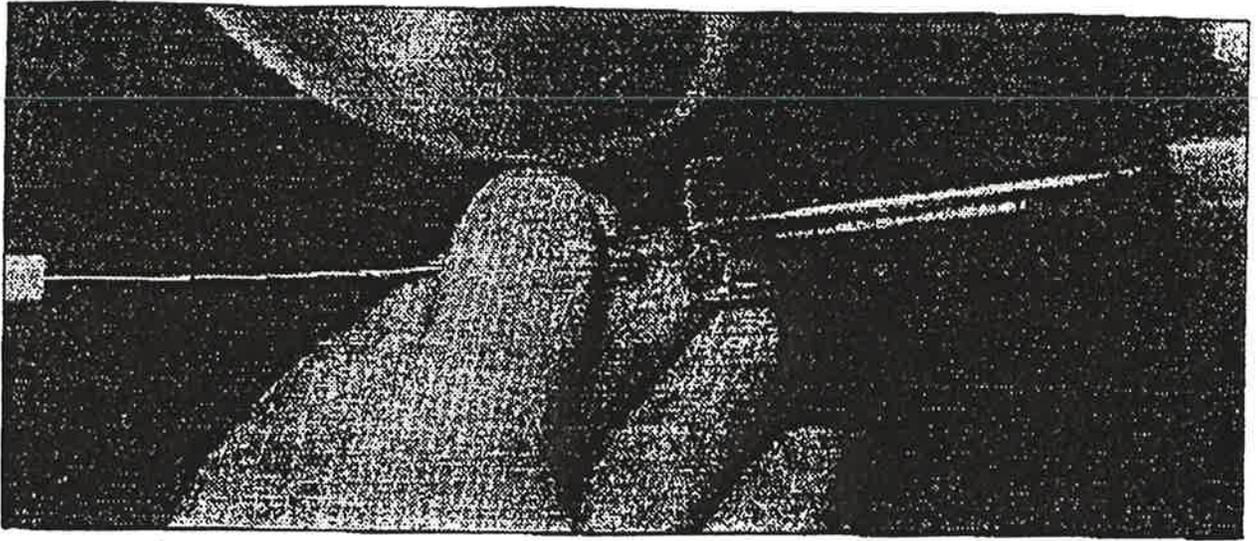


Close the tap and carefully pull the grey bottom tube out of the sheath until the tip of the sheath returns to its original position.

Open the tap and continue to inject the heparin solution until it drips from the pin vise area; close the tap.



Flush through the inner lumen



Fluid should flow from the end, and side holes of the tapered tip.

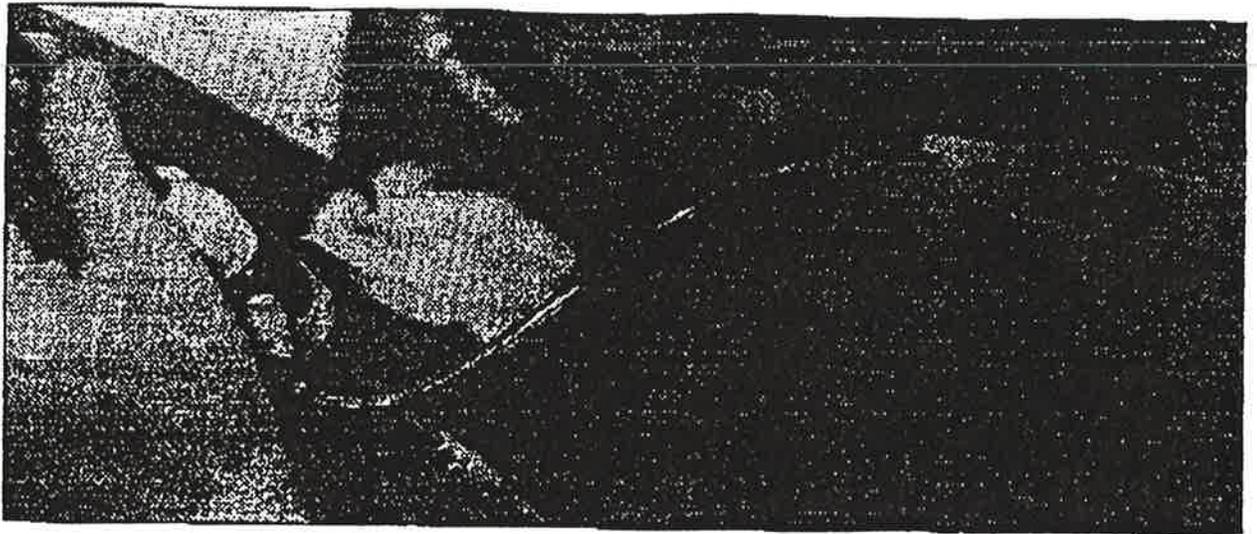


The device is now prepared.

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*Preparation of the
Extension Leg*

Strip off the peel away sheath, tighten the pin vise, and coat the surfaces with silicon as for main graft system



With the tapered tip uppermost flush with the extra strong heparin solution until fluid emerges at the sheath tip.



If difficulty encountered in injecting fluid, carefully withdraw sheath until flushing is possible and then return sheath tip to its original position after closing the tap.

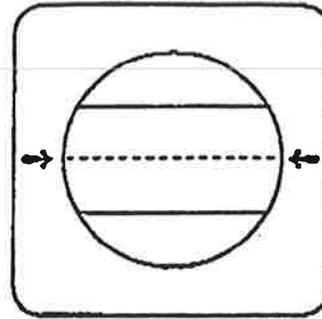
Flush through the inner lumen, and the device is prepared.

H&L-B ENDOSTENT

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EndoStent
Recommended
Setup and
Insertion Check
List

1. Close shutters to a narrow horizontal slit and mark the middle of the screen with markers on each side.



2. Set up patient on table over marker board system.
3. Check fluoro and adjust position of radiopaque ruler just to right of lumbar spine.
4. From angiogram or CT images, position wire markers in approximate positions of:
 - lower edge of renal arteries (L1/2 disc space);
 - aortic bifurcation (upper edge L5 – S1);
 - and any other landmarks that require marking (e.g., internal iliac origin).

At all times do positioning with wires in middle of screen and 0° tube tilt, with following exception:

- When positioning the renal artery marker. If infra renal neck is short and angled with respect to the table (horizontal plane), use a cranial/caudal tube tilt as near as possible to the aortic neck angulation.
5. Have injection pump set up with 100mL contrast and long connection tube.
 6. Have two pressure drips set up, each with 500mL heparinised saline (10,000 units/Litre)
 7. Expose both external iliac arteries.
 8. Insert slings around both vessels.
 9. Check which is the vessel for introduction of body of graft.
 10. Needle it with 19 gauge COOK arterial needle and insert:
 - wire guide,
 - 5 French sheath, and then
 - a pigtail catheter (5 French x 100cm).
 11. Give additional heparin (suggest 2000–3000, units) and antibiotic, if required.

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12. Perform angiography at each site of wire markers with the markers in centre of field. Adjust position of markers as necessary and re-angio. Suggest:

- 10mL/sec for 10mL — renal;
- 8mL/sec for 6mL — bifurcation.

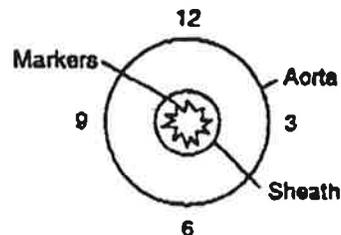
If tube angulation used with angled neck, also do angiography of renal area with vertical beam and note level of renals with respect to radiopaque ruler.

13. Insert AES .035 260cm wire guide to aortic arch.
14. Remove pigtail catheter and 5 French sheath and replace with the previously prepared main body "One Shot" introduction device.
15. Carefully advance Coon's dilator and sheath into the artery and with an oscillating rotational action advance until the bottom of the proximal (uncovered) stent is at the level of the renal arteries.

In any rotational action rotate all of the components of the system (from outer sheath to inner guide wire).

NB. Dilator softens as it warms to blood heat; do not rush it; do not let wire guide advance.

16. Check position of wire guide in arch.
17. Connect pressure drip to the haemoreduction valve.
18. Centre on "bifurcation" wire marker. Switch I.I. to maximum magnification. Check that short leg is above bifurcation. Rotate whole system until the markers on the bottom of the short leg show it to be on the side of the contra-lateral iliac. Adjust rotation until markers show short leg to be between 10.00 and 12.00 o'clock on the right side, or 12.00 and 2.00 o'clock on the left.



19. Centre on "renal artery" marker and check position of the graft again (graft being just above the bottom of the top attachment stent which is encapsulated within the top cap).
20. Hold top cap steady in this position by firmly grasping the grey component and slowly withdraw the sheath.

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21. When the first two stents below the top cap have expanded, re-centre on the "bifurcation" wire marker. Re-check that the short leg markers are still above the bifurcation and have not otherwise moved.
22. Continue to withdraw sheath (making sure graft system does not move) until short leg expands into position.
Stop withdrawing sheath.
If absolutely necessary, system can usually still be rotated and moved up and down at this stage, but make sure that all components (from the sheath to the wire guide) are moved together (to avoid twisting leg of graft).
23. Go to opposite leg.
Insert:
 - arterial needle;
 - wire guide — standard .035", 145cm, 15mm J tip;
 - 5 French sheath; and
 - catheter (VanSchie 1, 2 or 3).
24. Manipulate wire guide, then catheter, through open end of short leg into body of graft.
The wire guide is not in the graft body if any part of it shows outside any of the body or short leg stents.
If difficulty is encountered, a RoadRunner wire guide (RFPC-.035-145cm) or an alternative VanSchie catheter may help, as may repositioning short leg opening.
25. With catheter tip at about mid level inside graft, do DSA to confirm position.
Suggest 5mL/sec for 8mL.
26. Insert 35-260-AES wire guide until doubled over inside graft body and leave catheter in place.
27. Centre on "renal artery" marker wire (use tube angulation if necessary).
28. Remove wire guide. Do angiogram through top cap cannula (10mL/sec for 15mL) to re-check position of renal arteries.
29. Replace wire guide and do final adjustment of graft position.
30. Remove the safety lock from the black top cap trigger wire release device. Withdraw and remove the trigger wire by sliding the black wire release device off the handle, and then remove via its slot over the wire guide.

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31. Unlock pin vise half a turn and deploy top stent by advancing top cap cannula 1mm-2mm at a time, controlling the position of the graft by retracting or advancing the large diameter grey section of the introducer, and sheath.

Monitor and adjust graft position constantly during deployment.

32. Advance contra-lateral wire guide through open graft, up and to the arch. Re-check the position of the other wire guide in the arch.
33. Remove catheter and 5 French sheath. Replace with the previously prepared "One Shot" introduction system for the extension leg.
34. Carefully advance Coon's dilator and sheath into the artery and with an oscillating rotational action advance slowly until the extension leg is overlapped one full stent inside the short leg. If there is any tendency for graft to move during this manoeuvre, hold it in position with traction on the grey section of the introducer and the sheath.
35. If internal iliac wire markers in use, do final check of position of distal end of the extension leg and reposition if necessary.

To deploy, hold the extension leg in position with the pusher while withdrawing the sheath.

36. Withdraw the tapered tip of the introducer back through the extension leg by withdrawing the pusher.
37. Re-check the position of the wire guides in the arch.

Connect the second pressure drip to the haemoreduction valve.

38. Go to the main iliac limb.

If internal iliac wire markers in use, do final check of position of distal end of the main iliac leg and then fully deploy this leg by withdrawing the sheath, adjusting its position as necessary during withdrawal with the grey bottom attachment component of the system.

39. Remove the safety lock from the white bottom attachment trigger wire release device. Withdraw and remove the trigger wire.
40. Check that the pin vise is released.

Hold the sheath so that it does not move.

Hold the 18 gauge cannula that is attached to the top cap, and Coon's dilator, so that it cannot move.

First withdraw the bottom attachment device 1cm. By

withdrawing the grey component of the system, and then using a rotational action advance it over the 18 gauge cannula until it docks with the top cap.

If obstruction occurs, withdraw 5mm and re-advance with more rotation.

41. Lock up the pin vise and withdraw assembly through graft and into sheath by pulling on the 18 gauge cannula.

Make sure that the sheath does not move.

Make sure that the wire guide stays in place.

42. Re-check arch for position of wire guides.
43. Remove complete introduction assembly from over the wire guide and replace with the 30mm latex balloon.

NOTE: Preparation for latex balloon:

- Lubricate balloon with a thin layer of silicone.
- Fill 20mL syringe with 20mL contrast diluted 2:1.
- De-bubble balloon by sucking back as far as possible with the 20mL syringe.

44. Advance latex balloon over wire guide to level of renal arteries.

Angioplasty in the area of the attachment stent and then the infrarenal neck, starting proximal and then working more distal to reduce the possibility of dislodging soft atheroma into the lumen.

45. Withdraw to the iliac limbs and gently expand both iliac limbs and in particular the area of overlap of the extension leg.
46. Remove large latex balloon, replace with pigtail catheter and do check angiograms.

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