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Replacement of the Descending Aorta using the daVinci Surgical System in a Sheep Model: Comparison of Anastomosis Techniques

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ABSTRACT

Objective: The purpose of our study was to assess the feasibility of a closed-chest replacement of the descending thoracic aorta utilizing the daVinci surgical robotic system and to compare hand-sewn running anastomosis to interrupted nitinol clips (Coalescent Surgical).

Methods: Six sheep underwent replacement of the descending aorta using Intuitive's daVinci surgical system. Using the daVinci, the descending aorta was dissected out and individual intercostal arteries were clipped and divided. Following systemic heparinization, the aorta was occluded using percutaneous vascular clamps (Chitwood clamps). The descending aorta was excised and replaced with a woven graft. The proximal and distal anastomoses were varied in each animal between a running 4-0 polypropylene technique and interrupted nitinol clips. Anastomoses were inspected for hemostasis and tested for burst strength.

Results: Five of six animals survived the procedure. The average procedure time was 93 minutes. Cross-clamp times range from 55 to 25 minutes (average of 37 minutes). There was no significant difference in time between U-clip anastomoses (17 ± 4.8 minutes) and sutured anastomoses (10.6 ± 3.1 minutes). The burst pressure was higher for sutured anastomosis than for U-clips (214.6 ± 61 and 110 ± 35, respectively).

Conclusion: Replacement of the descending aorta with a graft is feasible in a closed chest model utilizing Intuitive's daVinci surgical system. While mean burst strengths were higher with a running sutured anastomosis, there was no difference in anastomotic time or ultimate hemostasis between techniques.

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INTRODUCTION

Pathologic conditions involving the descending thoracic and abdominal aorta are common and range from pediatric conditions to adult acquired diseases. Interest in the past few years has been focused largely on endovascular treatment of aortic pathology in an effort to limit morbidity related to open surgical procedures. However, not all patients are candidates for an endovascular procedure. Current indications and limitations of endovascular treatment of thoracic aneurysm continue to evolve and have been listed multiple times (Brunkwall 2003, Carroccio 2003). Recently, computer-assisted or robot-assisted surgery has made possible complex repairs of heart valves, coronary bypass procedures, as well as general thoracic and abdominal surgery through an endoscopic approach, thus limiting surgical morbidity and possible mortality.Thoracic aorta aneurysms have a high prevalence amongst the population. A previous study of 260 patients with thoracic aortic aneurysms found 40% of the aneurysms were ascending while 60% were descending (Pressler 1985). Aortic aneurysms are commonly caused by atherosclerosis, high blood pressure, Marfan's disorder, congenital malformations, trauma and syphilis. The standard of treatment in the past has been open surgical repair; although endovascular treatment is growing in popularity, however it is limited to select individuals. A minimally invasive approach using the robotic system has the potential for superior surgical intervention for thoracic aorta surgery.

The purpose of our project was to show feasibility in descending aortic replacement in a totally closed chest procedure utilizing Intuitive's daVinci surgical robotic system. In addition, a comparison was made between a running hand-sewn anastomosis using a 4-0 polypropylene suture (a conventional hand-sewn anastomosis) and an interrupted anastomotic technique using coalescent U-clip technology.

MATERIALS AND METHODS

The daVinci surgical system by Intuitive Surgical consists of a surgeon's console, a surgical cart, and a video tower imaging system. The patient-side cart consists of a surgeon-controlled camera which provides three-dimensional imaging and is available in zero degree, 30 degree angled up or 30 degree angled down scopes. It comes with two or three surgical instruments which are controlled by the surgeon at the console. The sur-

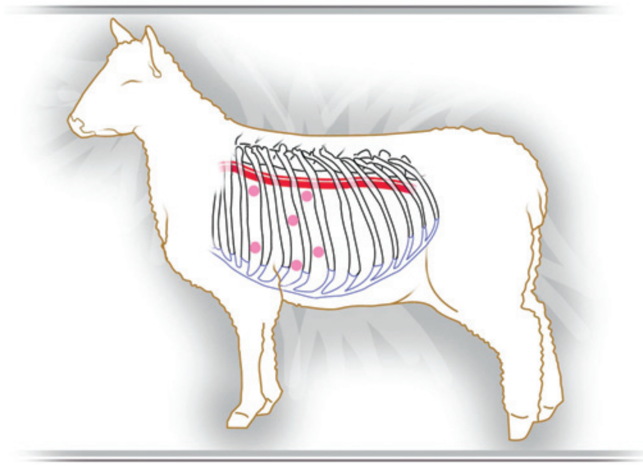

Figure 1. Animal position and port locations.

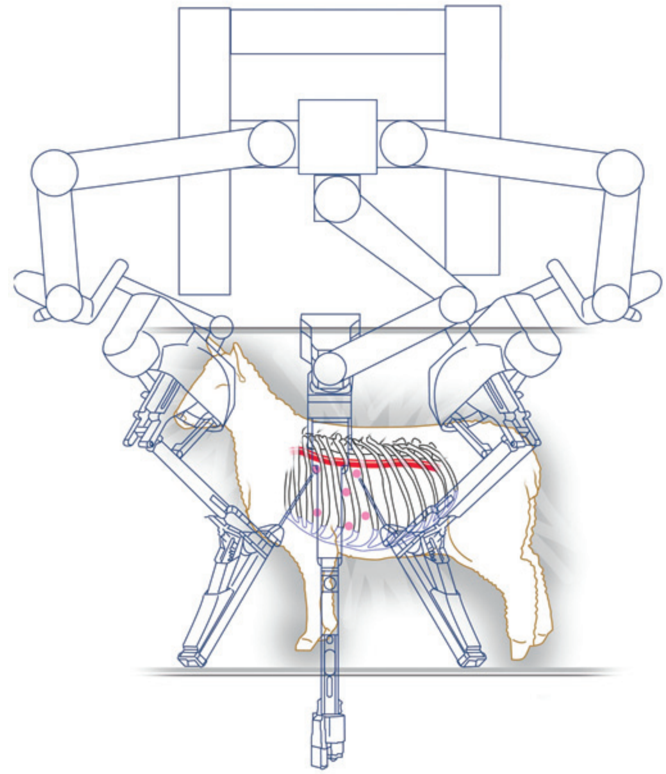

Figure 2. Position of the daVinci surgical system.

geon operates at the console while viewing a three-dimensional image of the surgical field. This technology translates the exact movements of the surgeon to precise, real-time movements using various surgical instruments that are available. These instruments are 8 mm instruments and provide 6 degrees of freedom. Movements can be scaled into three different levels, translated in a one-to-one, three-to-one, or five-to-one scaling. This system allows the surgeon complete control with full range of motion fine tissue manipulation capabilities with the enhancement of magnified three-dimensional vision, while simultaneously enabling minimally invasive surgical techniques through port access surgery. A detailed description of this system is provided by Falk et al (2000).

Good Samaritan Hospital Institutional Animal Care and Use Committee (IACUC) approved the experimental protocol for 6 ovine. Animal care complied with the regulations of the Animal Welfare Act 9CFR of the Animal and Plant Health Inspection Service, US Department of Agriculture.

A total of 6 ovine were used for this study. After safe induction of general endotracheal anesthesia, a long endotracheal tube was positioned into the right lung. IV access was obtained via jugular line and IV fluid was infused using Lactated Ringers 4 to 8 mL/kg/hour to prevent hypotension and dehydration. Pulse oximetry was measured throughout the procedure. The animals were placed in the right lateral decubitus position with the left side up and prepped and draped (Figure 1). The daVinci camera, 30 degree, was inserted to a 12 mm port site placed in the mid-thoracic cavity in the mid-axillary line, and CO_2 insufflation was used at a mean pressure of 8 to 10 mm of mercury. The aorta was visualized and the right and left robotic arms were placed in the anterior axillary line in the 4th and 7th interspace (Figure 2). A working port was placed in the posterior axillary line.

Using the daVinci system, the aorta was dissected out for a length of approximately 15-20 cm using a DeBakey in the left arm and a spatula cautery in the right arm. The intercostal branches were dissected out, clipped and divided using scissors. Once a segment of aorta had been completely mobilized, the animals were heparinized at 3 cc per kg and the aorta was cross-clamped proximally and distally using percutaneous aortic clamps (Chitwood clamps manufactured by Scanlon International) (Figure 3). The aorta was then excised and removed through the access port and an appropriately sized Hemashield graft was selected. The graft was then

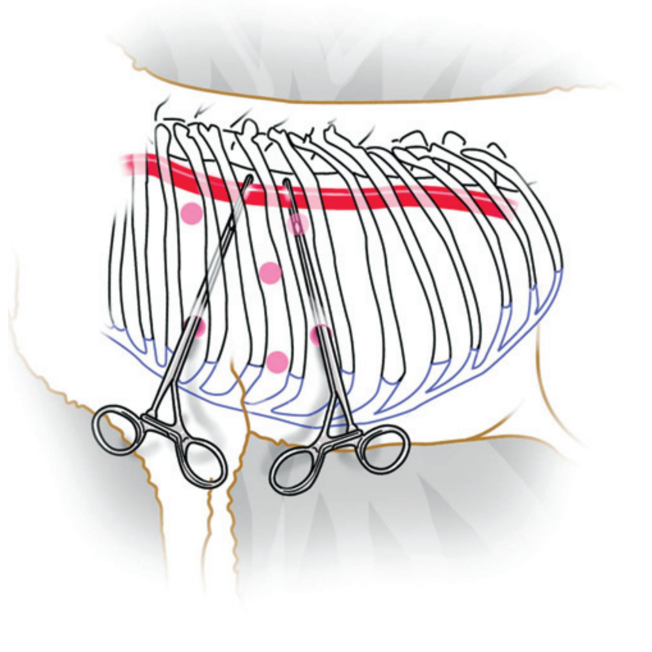

Figure 3. Clamping the aorta.

Case Information

	Case #1	Case #3	Case #4	Case #5	Case #6
Date of operation	02/03/2004	02/06/2004	02/11/2004	02/11/2004	02/12/2004
Age, y	2	4	3	3	2
Weight, kg	55	64	70	55	32
Sex	Female	Male	Male	Male	Male
Proximal anastomosis (suture/U-clip)	Suture	Suture	U-clip	Suture	U-clip
Distal anastomosis (suture/U-clip)	U-clip	U-clip	Suture	U-clip	Suture
Total operative time, min	119	127	61	82	76
Aortic cross-clamp time, min	44	55	25	35	26
Time of suture anastomosis, min	13	10	6	14	10
Time of U-clip anastomosis,* min	20	23	16	16	10
Number of sutures placed	Running	Running	Running	Running	Running
Type of suture	4-0 Proline	4-0 Proline	4-0 Proline	4-0 Proline	4-0 Proline
Number of U-clips placed	12	12	14	12	12
Type of U-clip	s90, 26 mm	s90, 26 mm	s90, 26 mm	s90, 26 mm	s90, 26 mm
Size of graft, mm	14	14	14	14	12
Vessel diameter, mm	12	14	13	12	12
Unclamp hemostasis U-clip anas (leak/no leak)	leak	leak	leak	leak	leak
Unclamp hemostasis suture anas (leak/no leak)	no leak	no leak	leak	no leak	no leak
Burst-pressure – sutured anast. (mm Hg)	>250	>250	110	>250	210
Burst-pressure – U-clip anast. (mm Hg)	80	70	140	150	110
CO_2 insufflation pressure, mm Hg	14	8	10	10	6
Heart rate pre-op, bpm	80	137	128	158	120
Heart rate post-op, bpm	115	88	132	148	122
Oxygen saturation pre-op, %	98	87	98	87	97
Oxygen saturation post-op, %	99	99	92	97	99
Total blood loss, mL	200	100	100	50	50

*U-clip anastomosis stopped leaking after 15 minutes in all cases.

sutured in with alternating techniques between the proximal and distal anastomosis on each animal. The two techniques that were alternated were a running 4-0 polypropylene on an RB-1 needle, or interrupted U-clips using S-90 U-clips. At the conclusion of the anastomosis, the clamps were removed and the anastomosis tested for hemostasis.

At this point, the daVinci system was removed, the animals were fluid resuscitated and the chest cavity opened and a final inspection taken of the hemostatic quality of the grafts in the open chest. The animals were then sacrificed and the descending aorta was harvested fresh and burst pressures were measured on both proximal and distal anastomosis with a roller-pump.

RESULTS

Five of six animals survived the procedure and made the study population. One animal, the second case, expired secondary to hypotension shortly after placing the cross-clamps. Procedure time ranged from 127 minutes to 61 minutes with a mean of 93 ± 28.6 minutes (Table). There was a reduction in procedure time from the first 2 cases to the last 3 cases. Procedure time was defined as the time from skin incision to the removal of the robotic cart. Aortic cross-clamp time ranged from 55 minutes to 25 minutes with a mean of 37 ± 12.7 minutes. Aortic cross-clap time decreased from the first 2 cases to the last 3 cases. There was no significant difference in anastomotic time between U-clips (17 ± 4.8 minutes) and sutured anastomoses (10.6 ± 3.1 minutes). An average of 12 U-clips were used per anastomosis. The sizes of the grafts inserted were four 14 mm grafts and one 12 mm graft. All of the anastomoses performed with U-clips initially leaked, but by the time the chest was opened at the completion of the procedure, all of the anastomoses were hemostatic. Under the hand-sewn anastomosis, only one anastomosis leaked initially with cross-clamp removal and this was also hemostatic when the chest was opened. Burst pressure was higher for sutured anastomosis than for U-clips (214.6 mm Hg ± 61 and 110 mm Hg ± 35, respectively). The heart rates pre-operatively ranged from 158 to 80 with a mean of 125. Post-operatively heart rates were 148 to 88 with a mean of 121. Oxygen saturations pre-operatively ranged from 98 to 87 and oxygen saturation post-op range from 99% to 92%.

DISCUSSION

Minimally invasive surgery using the robotic system has led to advances in technique, shorter hospital stay and rapid recovery. Intuitive Surgical's daVinci robotic system provides resolution and magnification, with three-dimensional visualization, for precise surgical procedures on microscopic structures. It enhances fine motor skills and reduces tremor in the surgeon. This robotic system has made advances in the past several years and is now used in a broad range of surgical procedures, most notably in cardiothoracic surgery.

Thoracic aortic aneurysms have an annual occurrence of approximately 6 per 100,000 people (Gowsa 2003). Repair of these aneurysms are often recommended in patients that are symptomatic, diameter greater than 6 cm or an aneurysm diameter twice that of a normal aortic segment (Baue 1996). Thoracic aortic aneurysms are often present in high-risk elderly patients with multiple co-morbidities including; coronary artery disease, obstructive pulmonary disease and hypertension. Besides these pre-operative stresses surgical repair of the thoracic aorta adds additional risks of paraplegia, renal insufficiency, blood loss, pulmonary insufficiency and left ventricular cardiac strain. Historically, open surgical repair has been the gold standard; however, new advances in minimally invasive techniques including endovascular stent placement and robotic surgery have the potential to decrease morbidity and mortality. Endovascular stent grafting has had an enormous impact on the treatment of abdominal aortic aneurysms (AAA). Recent FDA approval of a thoracic endograft holds great promise for minimizing trauma in treating thoracic aortic aneurysms (TAA). However, due to selection criteria and limitation of endografts, not all patients will be candidates. Robotic surgery adds the additional benefit of replacing the diseased aorta with a graft whereas endovascular repair is only palliative and risk of aneurysmal rupture may remain.

This study performed end-to-end anastomosis with a Hemashield graft in the descending thoracic aorta using closed chest surgery with the daVinci robotic system is feasible in the sheep model. The burst pressure was higher in sutured anastomosis of 214.6 mm Hg compared to 110 mm Hg with U-clips; however, both gained hemostasis postoperatively and were found adequate techniques. These findings are consistent with those produced from the Stanford University robotic thoracic aorta study (Malhotra 2002).

Previous robotic surgery on animal models, and some human cases, have shown success including thoracic aorta to femoral artery bypass (Tozzi 2003), mitral valve repair (Kypson 2003), atrial septal repair (Wimmer-Greincker 2003) and coronary artery bypass graft. Two separate surgical trials from the University of Texas and Stanford University (Malhotra 2002) have shown aorta replacement using the robotic system to be safe and effective, although suturing the diseased aorta remains a challenge when using the daVinci system.

Graft placement of the descending aorta using Intuitive's daVinci surgical robotic system in a closed chest model is feasible and reproducible. Anastomotic techniques consisting of either Coalescent U-clips or running 4-0 polypropylene resulted in equivalent results, with the exception of higher burst strength that were obtained with a running suture. This technique has potential for repair of the transverse aortic arch and ascending aorta.

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DISCLOSURE

Dr. J. Michael Smith receives honorariums for consulting services for Intuitive Surgical.

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