Aortic Dissection as a Complication of Cardiac Surgery: Report From The Society of Thoracic Surgeons Database

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Background. **Aortic dissection as a complication of cardiac surgery is a rare but often lethal event. We sought to determine the frequency of this complication in the STS (Society of Thoracic Surgeons) database as well as the outcomes of patients who suffer intraoperative aortic dissection. We then developed a model to identify preoperative characteristics and intraoperative factors associated with the complication.**

Methods. **All patients from the STS database who underwent coronary artery bypass grafting, aortic valve surgery, or mitral valve surgery were included. Exclusion criteria included any patient who had aortic dissection listed as a reason for urgent or emergent operation. Data collected were then analyzed to describe the frequency of aortic dissection as a complication as well as its consequences. We then analyzed a more recent era that included information on arterial cannulation site (femoral-other versus aortic) to identify risk factors for aortic dissection.**

Results. **Of 2,219,991 patients analyzed, 1,294 suffered aortic dissection as a complication of their surgery, for an incidence of 0.06%. This complication frequently led to catastrophic results, with 615 of 1,294 (48%) operative mortality. A logistic regression model was created based on 2004 to 2007 STS data. Of 680,025 patients analyzed, 436 patients suffered an aortic dissection. The analysis yielded nine significant risk factors including femoral arterial cannulation, preoperative steroids, and Asian race; the presence of diabetes appeared to be protective.**

Conclusions. **Aortic dissection is a rare but catastrophic complication of cardiac surgery. Femoral cannulation is associated with an increased frequency of this complication.**

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Since the initial description in 1960 [1] of a retrograde dissection after femoral artery cannulation, aortic dissection has been recognized as a rare but often lethal complication of cardiac surgery. A small number of single-center series exist in the literature, with incidences reported as 0.16% to 0.35%. Despite attempts at repair, mortality in these reports ranges from 25% to 50% [2–4]. The Society of Thoracic Surgeons (STS) database presents a unique opportunity to examine this rare event. With the statistical power afforded by the large number of patients in the database, we sought to define incidence as well as identify previously unrecognized risk factors for this catastrophic complication of cardiac surgery.

Material and Methods

This study was approved by the Duke University Institutional Review Board; the requirement for consent was waived. The STS Adult Cardiac Surgery Database was established in 1989 to report surgical outcomes after cardiothoracic surgical procedures [5]. Patient data are entered from sites using uniform definitions (available online at http://www.sts.org) and certified software systems. Although participation in the STS database is voluntary, data completeness is high, with overall preoperative risk factors missing in fewer than 5% of submitted cases. The accuracy of submitted cases has been confirmed in independent comparison of hospital coronary

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artery bypass graft surgery (CABG) volume and mortality rates reported to the STS versus those reported to Centers for Medicare and Medicaid Services [6].

For the current study, patients who underwent operation for aortic valve surgery, mitral valve surgery, and (or) CABG in the years 1996 to 2007 were included in the initial analysis to determine incidence and outcomes of intraoperative acute dissection complicating adult cardiac surgery. To investigate risk factors for the complication, these same procedures were again analyzed for the years 2004 to 2007, when the database questionnaire contained information regarding cannulation site. Any patient listed as having undergone urgent or emergent surgery with aortic dissection cited as the indication for operation were excluded. Patients who underwent cardiac surgery without the use of cardiopulmonary bypass were also excluded, as we could not analyze these patients in a model that included cannulation method. Data from sites with more than 20% patients without any complication information were also excluded. Data were fit in logistic models using generalized equation estimation to account for within-site correlation. Parsimonious subsets of variables were selected from the candidate variables using a backward selection (cutoff, $p = 0.05$).

Results

From 1996 to 2007, 2,219,991 patients were analyzed and 1,294 were identified as having suffered aortic dissection as a complication of their surgery, for an incidence of 0.06%. Demographic information for those patients who suffered aortic dissection as well as those who did not can be found in Table 1. The rates per procedure were 75 of 128,986 (0.06%) for isolated mitral valve surgery, 1,053 of 1,913,666 (0.06%) for any CABG ± aortic and (or) mitral valve, and 166 of 177,339 (0.09%) for isolated aortic valve surgery. The rate for cardiac procedures that did not utilize cardiopulmonary bypass was 0.04%. This complication frequently led to catastrophic results, with 615 of 1,294 (48%) suffering operative mortality. Despite the rarity of the complication, it accounts for 0.7% of all deaths among patients analyzed. Other complications were far more frequent in the aortic dissection group as well, including stroke in 119 of 1,294 (9.2%) and renal failure in 175 of 1,294 (13.5%) (Table 2).

A logistic regression model was created based on 2004 to 2007 STS data. The advantages of using the later data set for the logistic regression model were the following: (1) aortic dissection was available as a reason for emergent operation after the year 2000, therefore making the data on intraoperative aortic dissection "cleaner"; (2) this era also included data on arterial cannulation site. Of 680,025 patients analyzed, 436 patients suffered an aortic dissection. The analysis yielded nine significant risk factors including femoral arterial cannulation, preoperative steroids, and Asian race; the presence of diabetes appeared to be protective (Table 3). The effects of body surface area were complex, demonstrating a positive association at the extremes of measurement (Table 4).

Comment

Only through the STS database could a cohort of 1,294 aortic dissections occurring as a complication of cardiac surgery be available for analysis. This study demonstrates the power of the database to describe a phenomenon previously reported only in small numbers by single-center retrospective analyses.

The present report confirms the highly lethal nature (roughly 50% mortality) of aortic dissection when it occurs as a complication of cardiac surgery. This is approximately double the operative mortality for repair of acute type A aortic dissection reported in the International Registry of Acute Aortic Dissection database [7]. Potential explanations for the increased mortality with intraoperative dissection are speculative, but may include the need to address the original cardiac disease requiring operation in addition to the superimposed dissection, difficulties obtaining alternative access for cardiopulmonary bypass in a timely manner after dissection occurrence, and, similarly, difficulties with cerebral and myocardial protection related to either dissection-induced malperfusion or the unplanned need for alteration in cannulation site necessitated by the dissection. In addition, rupture of the descending thoracic or thoracoabdominal aorta, as may occur in the case of retrograde dissection from a femoral cannulation site, is especially difficult to repair through a sternotomy incision. There are almost certainly other unknown factors involved as well.

Patients with a naturally occurring aortic dissection who survive to the operating room represent a select population in that they did not suffer an immediately lethal complication of the dissection such as aortic rupture, cardiac tamponade, or dissection of the left main coronary artery. In the International Registry of Acute Aortic Dissection database, iatrogenic dissection represented 5% of the total population, and of these, 69% were caused by previous cardiac surgical procedures [8]. Given the large number of cardiac surgical procedures performed each year, it is reasonable to believe that a low but significant percentage of all aortic dissections are caused by heart surgery.

The mortality and morbidity associated with intraoperative dissection emphasize the importance of prevention. Any aortic or peripheral vessel manipulation can be the source of dissection, including cannulation, partial or complete cross-clamps, proximal anastomotic sites, and even an intraaortic balloon pump. As such, all surgical manipulations should be performed in a manner designed to minimize aortic trauma and with technical precision. Although the exact mechanism of the iatrogenic aortic dissections in this study cannot be gleaned from the data available, it is probably prudent to avoid, if possible, clamping a pressurized aorta, torquing of a partial clamp if one is utilized, and cannulating significantly diseased vessels.

Intraoperative dissection is easily recognized. The ascending aorta is typically blue and often expands rapidly. Intractable bleeding is often seen at surgical sites (eg,

Table 1. Demographic Information for Era 1996 to 2007 (n = 2,219,991)

Variable	No Aortic Dissection (n = 2,218,697)	Aortic Dissection (n = 1,294)	*p* Value
Age (median) IQR (25th–75th)	67 (58–74)	72 (64–77)	<0.001
BSA IQR (25th-75th)	1.96 (1.8–2.1)	1.90 (1.7–2.1)	<0.001
Tobacco use (%)	1,291,810 (58)	704 (54)	0.059
Gender (female) (%)	692852 (31)	499 (39)	<0.001
Hypercholesterolemia (%)	1,343,722 (61)	722 (56)	<0.001
Renal failure (%)	123,444 (6)	96 (7)	0.004
Hypertension (%)	1,582,604 (71)	995 (77)	<0.001
Chronic lung disease (%)	343,196 (16)	224 (17)	0.067
Immunosuppressive treatment (%)	44,928 (2)	38 (3)	0.020
Peripheral vascular disease (%)	326,397 (15)	276 (21)	<0.001
Previous CABG (%)	148,119 (7)	107 (8)	0.022
Previous other cardiac surgery (%)	49,908 (2)	41 (3)	0.026
Previous valve surgery (%)	43,995 (2)	36 (3)	0.039
Steroid use (%)	75,160 (3)	63 (5)	0.003
Left main disease (%)	461,127 (21)	232 (18)	0.011
Aortic stenosis (%)	306,703 (14)	213 (16)	0.006
Aortic insufficiency (%)	144,264 (7)	157 (12)	<0.001
Mitral stenosis (%)	56,869 (3)	31 (2)	<0.001
Mitral insufficiency (%)	236,292 (11)	179 (14)	0.004
Race			<0.001
Black (%)	113,248 (5)	52 (4)	0.067
Hispanic (%)	61,549 (3)	30 (2)	0.020
Asian (%)	28,997 (1)	35 (3)	<0.001
White (%)	2,014,903 (91)	1,177 (91)	0.022
Diabetes			0.026
None (%)	218,704 (10)	73 (6)	0.039
Noninsulin dependent diabetes (%)	483,468 (22)	204 (16)	0.003
Insulin dependent diabetes (%)	1,516,525 (68)	1,017 (79)	0.011
Cerebrovascular disease/cerebrovascular accident			0.006
No CVD (%)	1,929,993 (87)	1,089 (84)	<0.001
CVD, no CVA (%)	155,191 (7)	112 (9)	0.703
CVD and CVA (%)	133,513 (6)	93 (7)	<0.001
Reoperation			<0.001
None (%)	2,021,602 (91)	1,141 (88)	
One previous (%)	176,807 (8)	137 (11)	
Two or more previous (%)	20,288 (1)	16 (1)	
Number of diseased vessels			<0.001
Less than two (%)	444,997 (20)	374 (29)	
Two (%)	397,703 (18)	238 (18)	
Three (%)	1,375,997 (62)	682 (53)	
Status			0.010
Elective (%)	1,307,689 (59)	706 (55)	
Urgent (%)	799,886 (36)	441 (34)	
Emergent or emergent salvage (%)	111,122 (5)	147 (11)	
Cardiac procedure			0.001
Isolated mitral surgery (%)	128,911 (6)	75 (6)	
Isolated aortic surgery (%)	177,173 (8)	166 (13)	
Any CABG (%)	1,912,613 (86)	1,053 (81)	

BSA = body surface area; CABG = coronary artery bypass grafting; CVA = cerebrovascular accident; CVD = cerebrovascular disease; IQR = interquartile range.

Table 2. Complications

Variable	No Aortic Dissection (n = 2,218,697)	Aortic Dissection (n = 1,294)	*p* Value
Mortality (%)	82,068 (4)	615 (48)	<0.001
Need for reoperation (%)	152,217 (7)	490 (38)	<0.001
Reoperation for bleeding (%)	72,379 (3)	271 (21)	<0.001
Postoperative stroke (%)	41,735 (2)	119 (9)	<0.001
Coma >24 hours (%)	13,101 (1)	87 (7)	<0.001
Renal failure (%)	77,455 (3)	175 (14)	<0.001
Multisystem failure (%)	25,019 (1)	137 (11)	<0.001

proximal anastomoses) on the aorta. Arterial infusion pressure is typically high and can be accompanied by systemic hypotension. If any doubt exists, transesophageal echocardiography and epiaortic ultrasound are rapid confirmatory tests. Once recognized, the surgeon should immediately separate from cardiopulmonary bypass if possible, pursue an alternative arterial cannulation site, and then proceed with conventional dissection repair, which is probably best done using deep hypothermia and circulatory arrest for open distal anastomosis under these circumstances.

In the STS database, the timing of the complication of aortic dissection is not specified (other than occurring during the index hospitalization), and we therefore were unable to determine the relative frequency of intraoperatively recognized dissection compared with that in the early postoperative period. Previous reports have described about a 2:1 ratio of intraoperative to early postoperative dissections [3, 4].

There has been speculation in the literature that the frequency of aortic dissection in OPCAB (off-pump coronary bypass grafting) is increased relative to conventional on-pump CABG [9]. It has been hypothesized that application of a partial occlusion clamp to the pressurized aorta and (or) various other devices used for construction of proximal anastomoses in OPCAB increases the risk of aortic dissection [10, 11]. Though cardiopulmonary bypass was not a candidate variable in the model, the overall rate of aortic dissection in OPCAB patients was 0.04%, compared with 0.06% overall for CABG patients.

Table 3. Multivariable Model for Era 2004 to 2007 (n = 680,025)

Variable	Odds Ratio	95% CI
Later surgery year	0.83	(0.7–0.98)
Aortic stenosis	0.68	(0.53–0.87)
Insulin dependent diabetes	0.45	(0.28–0.72)
Noninsulin dependent diabetes	0.76	(0.62–0.94)
Age >60 years	1.05	(1.04–1.07)
Asian race	2.74	(1.62–4.62)
Preoperative steroid usage	1.69	(1.1–2.6)
Peripheral vascular disease	1.47	(1.16–1.87)
Femoral-other arterial Cannulation	2.67	(1.78–3.99)

CI = confidence interval.

Table 4. Body Surface Area (BSA) Effects in Multivariable Model

Label	Odds Ratio	95% CI
BSA ≤1.4 vs 1.8	1.63	(1.16–2.29)
BSA 2.0 vs 1.8	0.97	(0.90–1.05)
BSA 2.4 vs 1.8	1.42	(1.05–1.91)

CI = confidence interval.

In this study several previously unrecognized risk factors were identified as having an association with the complication. Preoperative characteristics such as Asian race (independent of body surface area), treatment with steroids, peripheral vascular disease, and age greater than 60 showed an association; it appears that patients with aortic stenosis and diabetes are less likely to suffer an acute dissection as a complication of their cardiac surgery. Notably, the use of a partial clamp did not demonstrate an association.

Importantly, femoral-other alternative cannulation site was associated with the complication. It should be recognized, as mentioned previously, that the treatment algorithm for intraoperatively recognized aortic dissection is to switch to an alternative arterial cannulation site (most commonly femoral cannulation) and thus it is unclear if the strong association with femoral arterial cannulation represents a cause of aortic dissection or a result. Furthermore, because of the lack of data, it is also unclear if cannulation through the axillary artery would demonstrate the same association. In the future, it may be helpful for the database to require the operative surgeon to declare a description of an "intended" and "actual" surgery as well as initial and, if necessary, secondary arterial cannulation sites.

There are several other limitations to the current study. The analysis of a low-frequency outcome in a retrospective database study can be problematic, as the effect of data entry errors are magnified. Additionally, fine detail of cannulation techniques, cannulae sizes, etc, are lacking. Importantly, information about other possible conditions that predispose to dissection are not available; most notably aortic size.

In summary, aortic dissection as a complication of cardiac surgery remains a difficult clinical situation with significant perioperative mortality and morbidity. Further adjustments to the data acquisition process in the STS database may allow a more refined analysis in the future to better define the role of femoral cannulation in the occurrence of the complication. Until more data are acquired, however, caution is recommended when considering femoral cannulation in patients with one or more of the other risk factors associated with aortic dissection as a complication of cardiac surgery.

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DISCUSSION

DR AUBREY C. GALLOWAY (New York, NY): That was a very nice presentation, Dr Williams. Dr Murray, thank you for the opportunity to discuss this important paper, which, like others in this session highlights the great potential of our national STS (Society of Thoracic Surgeons) database. At the same, this paper also highlights some of the deficiencies in the database as it currently stands. Mainly, data entry is not detailed enough for us to accurately assess causative risk factor and for us to be discriminatory in terms of how we prevent some of these major complications. You raised some of these issues in your paper and there are a couple of topics I would like to address.

First, exactly how were sites for cannulation coded? From the current database we don't know if a patient had an aortic dissection from an aortic cannulation site and then changed to femoral cannulation because of the dissection, which is a very typical practice. In such a case the procedure may have been coded as femoral cannulation, and the association with femoral cannulation was, therefore, a result of the dissection and not causative of the dissection. How do you account for this and doesn't that one fact mislead the analysis and invalidate some of the conclusions? The association of dissection with femoral cannulation may be strictly because the dissection had already happened. In fact, the data shows no impact of balloon endo-occlusion on the risk of dissection, and by nature those patients all had retrograde femoral perfusion.

We and others have found that small femoral vessels and peripheral vascular disease both increase the risk of dissection with femoral cannulation and your data also shows this. In the absence of peripheral vascular disease, and with good size femoral arteries, is the risk of retrograde dissection equivalent to central cannulation? Could you comment on that a little further?

Finally, you have addressed my last question somewhat but it is an important question for the future. How do you think we can change data entry into the STS database so that we can more accurately assess causative factors that predict the risk of aortic dissection? If we know the actual cause, then we can potentially lower the risk.

I congratulate you for taking on this task despite the limitations alluded to and I think this type of analysis is what we need to begin to do as a group. As an organization we have a very big lead in this capability compared to others, thanks to Dr Clark's work and encouragement years ago, and I believe we should use this capability as a Society to our advantage. Congratulations on a very nice paper.

DR WILLIAMS: Thank you, Dr Galloway. Well, you point out the chief weakness of this project. The possibility does exist that the femoral artery cannulation could be a response to the aortic dissection and this is why there is a strong association, and I think we just have to allow that this is possible. The lack of relationship between endoaortic balloon occlusion and dissection as an argument against the causative potential of femoral artery cannulation is a good point, but I don't think that the number of endoaortic balloon occlusions is near that of femoral artery cannulation, so you would lose a lot of statistical power in citing that as a root cause. I think that the proper response to the question is, well, this is a big problem. One percent of all the deaths after cardiac surgery are probably due to this and is there a controllable action? Is femoral cannulation a cause? And I think the only way to really find that out is to make these adjustments in the database. We have to say what the initial cannulation site is, because right now it is possible that it could have been charted as the central cannulation before the dissection and then femoral cannulation and then back to central cannulation after the aorta has been replaced. And it would be helpful to note initial cannulation site. And also typically we are not choosing an alternative cannulation site because we prefer that to central aortic cannulation, that there is a compelling reason for it and a comparison among alternative cannulation sites is also important. So I think we need to define precisely which artery we choose to cannulate.

DR AHMAD RAJAII-KHORASANI (Mashhad, Iran): I rise to congratulate the authors for this very important paper. I also thank the Society for the opportunity to reflect on two important points that I have experienced. One relates to prevention and the other relates to intraoperative diagnosis. First, aortic dissection as a complication of cardiac surgery, in general, is more frequently associated with elongated ascending aorta. This condition is usually seen in patients with tortuous aortas, usually in hypertensive patients or patients with pathologic aortas. Also, such aortas are thin and there is more chance of bleeding from the operation site, such as cannulation site or the proximal anastomoses. Preoperatively a tortuous aorta can be suspected by paying attention to the course of the catheter during cardiac cath. These important points, namely tortuous aorta and elongated ascending aortas as risk factors for intraoperative aortic complications are not previously mentioned in the literature and I believe they need to be emphasized.

Second, the importance of early diagnosis of intraoperative aortic dissection is emphasized due to the dynamic nature of the process. However, emphasis on immediate opening of the aorta for diagnosis, as suggested by some, should be modified to emphasis on dissecting the periaortic adventitia and demon-

strating presence of hematoma under the white aortic adventitia. With this maneuver many of subadventitial hematomas can be differentiated from true aortic dissection and unnecessary aortotomies are avoided.

I would like to again thank the authors again for this nice presentation and the Society for this opportunity.

DR WILLIAMS: Thank you for your kind comments. I think the question points out and in a way illustrates how we are trying to change cardiac surgery. Everybody has their own personal experiences with these extraordinarily rare complications, and we are trying to provide solid information based on scientific data to help us practice our craft now.

DR JAMES S. GAMMIE (Baltimore, MD): Dr Williams that was a beautifully presented paper. I know that you excluded off-pump coronary bypass from your initial analysis, but I wondered if you had gone back and looked at that. Many of us have concerns about a partial occlusion clamp on the beating full ascending aorta and have operated on those types of complications.

DR WILLIAMS: It is difficult to analyze off-pump surgery if you are going to simultaneously analyze perfusion methods, because perfusion methods are not included as information with off-pump surgery. The variables become mirror images of each other, so you can't really put it in a multivariable analysis that is going to include perfusion techniques. I will say that the raw data for off-pump surgery is not incriminating. The off-pump surgical aortic dissection rate is .04% relative to the on-pump rate of .06%. So at least from univariate analysis it does not appear that off-pump surgery is guilty of more aortic dissection. It is possible, though, and we should probably look at this in the database, if there is an association between partial clamp usage and off-pump surgery and aortic dissection, and that is not something that we have carried out thus far.

DR W. RANDOLPH CHITWOOD, JR (Greenville, NC): Thank you. That was a great paper, Dr Williams. I have one comment. I think these iatrogenic dissections are comprised of different phenotypes. Clearly, an ascending arch dissection when you cannulate the aortic root, especially in patients with atherosclerosis, can be a disaster, involving a high mortality. Also, some of the retrograde perfusions can be disastrous as well. But in minimally invasive cases with retrograde perfusion, we often see a different type of dissection. I have done over 2,000 of these retroperfusions and Professor Fred Mohr in Leipzig has done many more with retrograde cannulations. To notice a dissection immediately is key and I tell the residents and fellows to be vigilant when cardiopulmonary bypass is initiated. When one goes on the pump and the perfusionist tells us that the arterial pressure is high, it really is high until proven otherwise. The thing to do is ventilate and come back off the bypass to reestablish aortic integrate perfusion. I have had four of these types of cases; two in primary operations and two in redo procedures. I came off the pump immediately. We saw the dissection flap in the aorta by TEE (transesophageal echocardiography) and the dissection decreased with antegrade natural perfusion. They often heal and we come back later and operate through sternotomy and direct aortic arch cannulation. So it is not best to rush to an immediate sternum because as you will end up with a 50% mortality if you operate immediately on the dissection. Thus, I think there is a different phenotype for the later type of aortic dissection. In a nonatherosclerotic patient with femoral perfusion, if one causes a dissection, it is not necessarily an immediate panic. One should ventilate immediately and wean from bypass before you cool, assess the aorta with the echo, and then later on assess the aorta by CT (computed tomographic) scanning.

DR WILLIAMS: Thank you, Dr Chitwood. That is an interesting observation.