Repair of Traumatic Aortic Rupture

A 25-Year Experience

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Background: Surgical management of traumatic aortic rupture (TAR) is controversial, specifically whether distal aortic perfusion modifies the outcome.

Hypothesis: The outcome of patients who undergo repair of TAR is not dependent on the technique of repair.

Design: Retrospective review.

Setting: Tertiary care teaching hospital, level I regional trauma center.

Patients: One hundred fifteen victims (aged 5-81 years) of blunt chest trauma with aortic tear, presenting between January 1, 1974, and June 30, 1999.

Methods: Medical records were reviewed for prehospital and emergency department data, operative findings, and outcome. Statistical comparison was made using a paired 2-tailed t test.

Intervention: Surgical repair of TAR with (group 1) or without (group 2) distal aortic perfusion.

Results: Thirty-two patients in group 1 had TAR repair using active bypass (n=18) or Gott shunt (n=14). The clamp-and-sew technique was used in 83 patients (group 2). Primary repair was possible in 14 patients (44%) in group 1 and 69 patients (83%) in group 2. The average aortic cross-clamp time was 48 minutes for group 1 (range, 25-113 minutes) and 20 minutes for group 2 (range, 5-40 minutes) (P<.03). There was no significant difference in hospital mortality (6 [18.7%] of 32 vs 15 [18.1%] of 83) or the incidence of paraplegia (2 [6%] of 32 vs 5 [6%] of 83) between groups 1 and 2. During the last 15 years, 78 patients (73 in group 2) had repair of TAR with an operative mortality rate of 19.2%.

Conclusions: Acute TAR remains a highly lethal injury with no change in prognosis during the last 2 1/2 decades. Repair of TAR using simple aortic cross-clamping alone is feasible in the majority of patients without increased mortality or spinal cord injury.

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PATIENTS AND METHODS

Between January 1, 1974, and June 30, 1999, 128 patients with acute TAR were admitted to Loma Linda University Medical Center (Loma Linda, Calif). Seventy-six patients (60%) were admitted directly from the scene of the accident and 32 patients (40%) were transferred from another area hospital within a 10- to 50-mile (16- to 80-km) radius. Ten patients (8%) died of either massive hemorrhage or associated injuries during the initial evaluation; 3 others with severe head injury were managed medically. One hundred fifteen patients underwent surgical repair of the aorta. The hospital and operative records of these 115 patients constitute the material for this retrospective review. There were 90 male patients (78%) and 25 female patients (22%) aged 5 through 81 years (mean ± SD age, 35 ± 0.9 years). The aortic injuries were caused by rapid deceleration motor vehicle crashes (n=107), vehicular collisions with pedestrian victims (n=3), snowboarding (n=2), a parachute accident (n=1), and free fall (n=2).

This review is divided into 2 eras according to the period of surgical repair. The early era (n=37) spanned 1974 through 1983 and the late era (n=78) extended from 1984 through mid 1999. In the early era, the diagnosis of aortic disruption was confirmed by angiography in all patients. In the late era, at least 1 of the following 3 diagnostic modalities was used to assess aortic integrity: computed tomography (n=25), aortography (n=60), and tranesophageal echocardiography (n=10). Two patients with aortic injury and very unstable hemodynamics underwent emergency exploratory thoracotomy and repair based on the mechanism of injury and the chest roentgenogram findings. On admission, widening of the mediastinum was present on anterior-posterior chest roentgenograms in all patients except for 2, whose mediastinal widenings appeared 3 and 5 days after the injury.

Nine patients (8%) had an isolated aortic injury, while the majority of patients had multiple injuries with 2 to 6 systems involved (median, 3). Significant associated injuries included the central nervous system (n=35), head and neck fractures (n=38), other thoracic trauma (n=60), orthopedic fractures (n=86), soft tissue and vascular injuries (n=30), and abdominal visceral injury (n=43). The site of rupture was limited to the aortic isthmus, just distal to the origin of the descending aorta. Blunt trauma of the aorta resulted in complete circumferential transection of the isthmus in 68 patients, and a partial tear in 44 patients. Surgical repair was performed via a left posterolateral thoracotomy. Double-lumen endotracheal intubation was available to less than 65% of patients because of severe head and facial edema and cervical spine precautions. Patients were divided into 2 groups according to the adjunct technique used during the repair. Group 1 (n=32) had distal aortic perfusion during the repair with either a passive heparin-bonded (Gott) shunt (n=14), an active roller, or a centrifugal pump (n=18). In the subgroup with passive adjunct distal flow, the shunt was ventriculo-aortic in 5 patients, ventriculo-femoral in 2 patients, and aorta-aortic in 7 patients. Active distal circulatory support with systemic heparinization provided partial or total cardiopulmonary bypass using femoral-femoral bypass (n=3), ventriculo-femoral artery bypass (n=2), left atrial-femoral artery bypass (n=3), left atrial-distal aorta bypass (n=6), or pulmonary artery–femoral bypass (n=2). Distal perfusion pressure was not routinely monitored, but flow was usually maintained above an index of 1.2 L. Complete cardiopulmonary bypass and hypothermic circulatory arrest were used in 2 patients. Group 2 (n=83) underwent repair of the aortic injury using the clamp-and-sew technique only. The 2 groups were comparable with respect to age, baseline characteristics, and the presence of major associated injuries.

Direct, primary repair with 3-0 monofilament suture was possible in 14 patients (44%) in group 1 and 69 patients (83%) in group 2. When primary anastomosis was not performed because of the complexity of the injury, the friability of the aortic tissue, or the surgeon’s choice, a Dacron or a Hemashield (Meadow; Boston Scientific Corp, Oakland, NJ) tube was used as an interposition graft. The average aortic clamp time for group 1 was 48 minutes (range, 25-113 minutes) and for group 2, 20 minutes (range, 5-40 minutes) (P<.03). Forty-five patients (10 patients in group 1) had a laparotomy performed for repair of abdominal injuries, either immediately before (n=30) or after (n=15) thoracotomy.

Data are presented as means ± SEMs; a paired 2-tailed t test was used to determine the probability value.

MORBIDITIES

Significant postoperative complications developed in 43 (39%) of the 109 patients who survived the repair. Seven patients without preoperative neurological deficit became paraplegic following repair (Table). The 2 patients in the shunt subgroup, aged 28 and 33 years, were stable preoperatively, but had excessive aortic clamp times of 50 and 113 minutes. The 5 patients in group 2 had an average clamp time of 30 minutes (range, 6-40 minutes). One 28-year-old man suffered preoperative cardiac arrest after exsanguination from a free aortic rupture. He survived primary repair of the aorta, using 6 minutes of aortic clamp time and 20 U of blood, but developed postoperative paraplegia. Each of the other 4 patients, aged 26 to 46 years, who had spinal cord injury after TAR repair presented with hy-
Acute TAR is a relatively common injury of deceleration accidents; and only 15% to 23% of victims survive long enough to reach a hospital.11 Successful management of these multiply injured patients requires early recognition and prompt treatment. Currently, our diagnosis of TAR is based on chest roentgenogram, mechanism of injury, and helical computed tomographic scan. Angiography and transesophageal echocardiography are used selectively when the findings of noninvasive tests are equivocal.12 Surgical repair of TAR may be delayed in patients with other life-threatening conditions such as severe head trauma, massive abdominal hemorrhage, extensive burns, or severe respiratory insufficiency. In the absence of expanding mediastinal hematoma, increasing hemorrhax (if present), or prolonged anuria, management of such coexisting injuries takes priority over repair of TAR.13 Medical management of TAR, however, requires close hemodynamic and radiographic monitoring as well as adequate antihypertensive treatment. Endoluminal deployment of a covered stent at the aortic isthmus has been used for delayed treatment of subacute or chronic TAR.14 Successful stent grafting achieves complete exclusion of the pseudoaneurysmal sac, but can cause occlusion of the left subclavian artery and compression of the left main bronchus by the thrombosed pseudoaneu-

There is considerable controversy as to which is the best operative strategy to repair acute TAR.5-10 The techniques that involve distal aortic perfusion include heparin-bonded shunts and bypass (total or partial) with a roller or centrifugal pump; the clamp-and-sew technique involves proximal aortic occlusion without distal augmentation of flow. There are proponents of each technique, with preference based on survival and the incidence of postoperative complications, in particular paraplegia. Systemic heparinization required for roller pump support has been associated with significant complications in patients with untreated severe neurosurgical, orthopadic, visceral, and pulmonary injuries.15 Pate et al10 reported re-

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*Values are expressed as number of patients/total number unless otherwise indicated.
†No significant difference.

pair of TAR in 88 patients using cardiopulmonary bypass with 90.9% survival and no spinal cord deficit. However, the intracranial injury became worse after repair in 3 of 19 patients with serious head trauma.6 In another series reported by Gammie et al,2 the 24 patients who were given heparin for cardiopulmonary bypass had some form of assessment of their intracranial status before the operation. Two patients (7.7%) died but no new postoperative paraplegia was noted. Similarly, in our series, none of the 18 patients who underwent repair with active bypass developed paraplegia, but 2 patients died intraoperatively of exsanguinating hemorrhage. Although the majority of surgeons prefer to avoid systemic heparinization, cardiopulmonary bypass and systemic hypothermia are particularly desirable for repair of multiple aortic tears and arch vessel injuries.

Left heart bypass using a heparinless centrifugal pump has been a useful adjunct in the repair of TAR. This method of distal aortic perfusion unloads the left ventricle and offers more hemodynamic stability. Potential complications with this technique include injury to the left atrium, air embolization, and proximal hypotension causing decreased cerebral circulation. In 1989, Benckart et al16 published their experience with 17 patients who had TAR repair using the BioMedicus (Eden Prairie, Minn) pump for left atrial to femoral bypass. Three patients (18%) died but there was no postoperative bleeding or paraplegia. In a more recent report, Contino et al6 compared the results of the following 3 different approaches with the repair of TAR: clamp-and-sew (n = 9), left heart bypass with heparinless centrifugal pump (n = 24), and femoral-femoral cardiopulmonary support (n = 9) using a Carmeda-coated (Medtronic Inc, Minneapolis, Minn) circuit to minimize heparin requirements. The amount of blood loss was similar in all groups. There were no cases of permanent paraplegia in the 33 patients who had mechanical distal aortic perfusion. However, 5 (20.8%) of 24 patients with left heart bypass died postoperatively, and the 1 patient with postoperative paraplegia repaired by simple cross-clamping had a cross-clamp time of 45 minutes. Although the femoral-femoral bypass system with the Carmeda-coated circuit requires a small amount of heparin and an extra groin incision, its advantages to the left heart centrifugal bypass include its simplicity and ability to add a heat exchanger and membrane oxygenator, which is especially desirable in patients with severe pulmonary contusion.

The use of a heparin-bonded shunt is another technique that provides distal aortic perfusion, eliminates the need for systemic heparinization, and allows for some de-
compression of the left side of the heart. This approach requires proximal cannulation of the left ventricular apex, ascending aorta, or the left subclavian artery as well as the distal arterial bed. Moreover, such shunts are unreliable as the flow is dependent on adequate cardiac performance and may fail to provide consistent distal perfusion unless a flow meter and a large shunt are consistently used. In most series, the repairs of TAR with the Gott shunt were associated with the same risk of postoperative paraplegia as cross-clamping without bypass.

The concept of repairing TAR with simple aortic cross-clamping only was demonstrated by Mattox and associates, who in 1985 reported a collective review of 387 cases of TAR from 18 trauma centers. Paraplegia occurred in 4.5% of patients managed with partial cardiopulmonary bypass support, 8.3% of individuals in whom simple aortic cross-clamping was used, and 10.3% of those for whom shunt support was used, with mortality rates of 33%, 13%, and 15%, respectively. For the last 15 years, our group and others have preferred the clamp-and-sew technique because it is simple, expeditious, does not require extra incisions, and avoids complications associated with cannulation, bypass, and heparinization. Our experience of repairing TAR with (group 1) or without (group 2) distal aortic perfusion has demonstrated no significant difference in mortality or morbidity between the 2 groups. The operative mortality rate of 18% and the 6% incidence of paraplegia in each group are not different from those reported in other large series. Hilgenberg et al.20 in each group of patients managed with partial cardiopulmonary bypass support, 8.3% of individuals in whom simple aortic cross-clamping was used, and 10.3% of those for whom shunt support was used, with mortality rates of 33%, 13%, and 15%, respectively. For the last 15 years, our group and others have preferred the clamp-and-sew technique because it is simple, expeditious, does not require extra incisions, and avoids complications associated with cannulation, bypass, and heparinization. Our experience of repairing TAR with (group 1) or without (group 2) distal aortic perfusion has demonstrated no significant difference in mortality or morbidity between the 2 groups. The operative mortality rate of 18% and the 6% incidence of paraplegia in each group are not different from those reported in other large series. Hilgenberg et al.20 reported 42 repairs of TAR. Nineteen were performed with cross-clamping only, and 23 with Gott shunt. The incidences of paraplegia were 5.2% and 13%, respectively. They developed a logistic model that calculated the probability of paraplegia at less than 1% with a clamp time of 30 minutes, and less than 5% with a clamp time of 45 minutes, but the curve rises sharply at 50 minutes. The use of a shunt did not offer spinal cord protection or extend the safe cross-clamp time. The clamp-and-sew technique was used exclusively for the repair of TAR in 3 reported series by Antunes18 (n = 16), Sweeney et al.10 (n = 71), and Maggisono et al.11 (n = 35). The average aortic cross-clamp times were 21 minutes (range, 13-27 minutes), 24 minutes (range, 14-36 minutes), and 31 minutes (range, 6-60 minutes), respectively; the incidences of paraplegia were 0%, 1.4%, and 3%, respectively. In a prospective multicenter trial of TAR repair at 50 trauma centers, Fabian et al.21 evaluated the clamp-and-sew technique in 73 patients (35%) and the bypass technique in 134 (85%). The mortality of 31% was not affected by the method of repair. Postoperative paraplegia occurred in 18 patients (8.7%) and was associated with the clamp-and-sew technique (16.4% vs 4.5%, P = .002) and aortic cross-clamp times greater than 30 minutes (P = .01). A meta-analysis of 71 articles reporting outcomes of repair of TAR in more than 1400 patients revealed an operative mortality of 21.3%. The mortality rate of 16% associated with simple aortic cross-clamping was no different than the mortality rate (18.2%) associated with cardiopulmonary bypass. The average cross-clamp time and the incidence of paraplegia were 31.8 minutes and 19.2% for simple clamp-and-sew, 40.6 minutes and 11.1% for passive shunting, and 47.8 minutes and 2.3% for actively augmented distal perfusion. There was an increased incidence of paraplegia in the clamp-and-sew group when cross-clamp times were greater than 30 minutes. It has been our operative strategy in repairing TAR to rapidly achieve proximal control of the aortic arch via a pericardial or extrapericardial approach, minimize dissection of the distal aorta, preserve all uninterrupted intercostal arteries, avoid fluctuations in blood pressure, and attempt primary repair of the aorta whenever possible. During the late era of this series, 79.4% of patients had primary repair, compared with 56.7% during the early era; the majority (93.5%) had repair with simple aortic cross-clamping only. Primary repair of the aortic injury has several advantages over the use of a tube or patch graft. It is more rapid, less expensive, and has a lower potential for infection, suture line dehiscence, or pseudoaneurysm formation. Direct repair is certainly the preferred method in children, because it obviates the need for reoperation as the child grows. It is up to the individual surgeon to decide on the method of TAR repair based on his or her experience, skill, and accurate assessment of the extent of injury. Primary repair with simple cross-clamping should probably not be attempted if there is doubt about safely completing the repair within 30 minutes.

This study has several limitations. The data are retrospective, nonrandomized, and do not establish the superiority of any one technique over another. Nevertheless, this report confirms that the mortality associated with TAR is still relatively high and has not changed during the last 2½ decades. Moreover, repair of TAR using simple clamp-and-sew technique is feasible in the majority of patients without increased mortality or spinal cord injury.

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REFERENCES


**DISCUSSION**

David Follette, MD, Sacramento, Calif: The University of California, Davis, trauma and cardiac surgery groups had the privilege of presenting our experience with this injury at the Pacific Coast Surgical Association Meeting in 1974. At that time we presented 9 cases where we had used a totally heparin-bonded system and Carmeda-coated oxygenator. In preparation for this discussion I had the opportunity to look up our overall experience over the last 10 years. We have now operated on 34 cases using this system for repair of traumatic pseudoaneurysms of the aorta. Our center, like Loma Linda, is a tertiary academic center. The number of cases we see on an annual basis is virtually identical to what was experienced at Loma Linda. The injury severity scores are quite comparable as well. The mortality in our group of patients is only 8%, and all of the deaths were in elderly patients, more than 75 years of age. The incidence of paraplegia has been 0%, and we, like the authors, had one case where a patient had preoperative paraplegia and regained partial recovery after surgery.

I would like to compliment Dr Razouk on his discussion in the manuscript. I will share some of the information that he provided. Dr Fabian orchestrated a multicenter trial of 30 trauma centers looking at the different techniques for repair of pseudoaneurysms. In that series, 16.4% of patients with clamp-and-sew technique had paraplegia and 4% being repaired under bypass developed paraplegia. There was a significant correlation with cross-clamp times of greater than 30 minutes. Dr Van Opal performed a meta-analysis of 71 reported studies in over 1400 patients. The mortality in this analysis was identical to the Loma Linda Experience at approximately 20%. The incidence of paraplegia in clamp-and-sew was close to 20%; in the Gott shunt group, 11%; but with bypass techniques, 2.3%. Dr Razouk presented in his manuscript, though did not emphasize in his presentation, the 18 patients who they operated on in their earlier era with bypass techniques. Their incidence of paraplegia was 0% but there were 2 patients in that group who died of hemorrhage.

I have several questions for Dr Razouk. You presented 13 patients who were over 70 years of age. Did you notice in that group of patients any increased mortality? What criteria were used to select the patients who had either perfusion vs clamp-and-sew technique? Were there separate criteria to determine whether a passive shunt such as a Gott shunt, left atrial bypass, or a femoral bypass system would be used? Have you had any experience using a completely heparinless system such as what we have used at UC Davis?

You have given very impressive statistics for primary repair without the use of a graft. I personally would like to know how you select those patients. I find the aorta very friable and difficult to sew, and I believe it is extremely impressive that over 80% of your cases are repaired without the use of prosthetic material.

We, like you, have seen several cases of vocal cord paresis, which fortunately were corrected quite nicely with medicalization of the cord. Do you have any suggestions on how this complication can be avoided?

The paraplegia rate is equal in both of your groups, but you mention quite specifically that in clamp-and-sew patients who developed paraplegia they were either hypotensive or had other difficulties. If these patients were stabilized with either bypass or trauma resuscitation, do you believe this might affect your paraplegia rates in this group?

You mentioned in your manuscript the development of late pseudoaneurysms. Was this limited to your graft group or your primary group? Lastly, I would like to compliment you on putting the issue of the Gott shunt to rest. I personally feel that it is not an adequate technique.

Bill Long, MD, Portland, Ore: Sometimes I wonder if we are really talking about the same disease, because when we look at these series that have 100 cases, there is a mixture of types of traumatic ruptured thoracic aorta. Some of them have intimal tears only, and many of those can be treated with antihypertensive medication such as you would use with a type B dissecting aneurysm. Others have small pseudoaneurysms. Others have pseudoaneurysms with dissection causing pseudooccaion syndrome, and there is a fourth group that was freely bleeding into the thoracic cavity. I think the outcomes and the management of each group varies significantly. In my own experience in Portland, 1 can’t remember when I have last seen an intimal tear. Most of ours are pseudoaneurysms or free ruptures or dissections with coarctation type of syndrome. So I was wondering if the authors have broken theirs down by the pathology in terms of the outcome.

Secondly, there is the intimation that the prolonged clamp time with the patients who are on shunts as opposed to those who were just clamp-and-sew would indicate to me that the degree of difficulty was higher in the ones who were on shunts as opposed to the ones who just had clamp-and-sew. It would seem to me that if you can do a repair in 5 minutes, then the patient must have an intimal tear only.

My last question and comment has to do with delayed management of these ruptured thoracic aorta patients following a laparotomy or with a severe head injury. Do you ever put them on antihypertensive therapy for a few days, allow things to declare themselves, and then fix them in a “more elective” fashion?

William P. Schecter, MD, San Francisco, Calif: I noticed that a couple of patients exanguinated intraoperatively. Had you cannulated the patient before you began to mobilize the aorta and the aorta disrupted in front of you, do you think you could have saved those patients by putting the patient immediately on bypass and then sucking the blood up and pumping it back into the patient?

Gregory J. Jurkovich, MD, Seattle, Wash: I rise as a general trauma surgeon who doesn’t repair torn thoracic aortas myself, but who relies on my cardiothoracic colleagues. I have watched with interest the debate over clamp-and-sew vs the appropriateness of bypass and repair. I won’t dwell on what Dr Follette nicely emphasized in his review of the literature: namely that this report has a fairly high overall mortality rate that hasn’t changed in 2½ decades, and a worrisomely high paraplegia rate. What I would comment on however, is that from my standpoint, the patient before you began to mobilize the aorta and the aorta disrupted in front of you, do you think you could have saved those patients by putting the patient immediately on bypass and then sucking the blood up and pumping it back into the patient?
was it delayed for a day or 2? What was the cross-clamp time? These are just examples of potential confounders that I think should be examined before one can make the conclusion that clamp-and-sew or bypass is preferable.

**Robert J. Stallone, MD, Oakland, Calif:** Prior to the era of trauma centers in the East Bay, we had about 8 hospitals where trauma patients would go and so we looked up our series, both from one hospital that had cardiopulmonary bypass facilities and then the other hospitals that didn’t. From 1974 to 1985 we had 20 consecutive patients. Eight of these patients were repaired at the noncardiac centers, which used the clamp-and-sew technique, and 12 were done at the other hospital where we used partial heparin coated femoral-femoral bypass without using any systemic heparin. We had 2 mortalities and these were both secondary to head injuries. There were no incidences of paraplegia or renal failure. The comment that I would like to submit to the authors is that only one of our patients had a primary repair and in all of the other cases, including the 8 patients who were done without bypass, grafts were placed. I think in at least what I see with other surgeons who have had problems with these cases, when you do one of these cases with a clamp-and-sew technique you have to be determined to go in there, immediately get control obviously, and then place a graft in less than 30 minutes because if you try to do a primary repair and the aorta starts falling apart, you will just get into too long a cross-clamp time. These cases in the primary ruptures, traumatic transection, are usually normal aortas. They are relatively easy to repair. They are not like a ruptured thoracic aneurysm or dissection.

**John E. Connolly, MD, Orange, Calif:** I would like to congratulate the authors for adding their large series to the literature. My comments are directed to the devastating complication of paraplegia. All agree that if you can limit cross-clamping time to 30 minutes, the incidence of paraplegia is low—perhaps 3%, but this is still very significant to the patient. The authors today report that their incidence was 6%, both when they clamped and cut and when they used a shunt, concluding that a shunt was not helpful and therefore not indicated. Other reports in the literature have come to the same conclusion. The fallacy of these conclusions is that if the surgeon does not constantly monitor the distal aortic pressure and use it to control the bypass to maintain the distal pressure at 60 mm Hg or higher, the bypass is not effective. If paraplegia occurs with unmonitored bypass, it cannot be said that use of a bypass does not prevent paraplegia. The Gott shunt used in some of the authors’ bypass cases is available only as large as 9 mm in diameter. Thus its flow cannot be varied and its size prevents ideal distal aortic pressures, and thus may be associated with some paraplegia results. However, if it is the only available type of bypass, I believe it is better than no shunt. All of the series reported with no paraplegia have utilized a thrombogenic tubing with partial bypass, employing a BioMedicus pump controlled by constant monitoring of distal aortic pressure, which is maintained at 60 mm Hg or above. This is what I strongly recommend. This permits the surgeon plenty of time to perform carefully whatever he encounters, including an interposition graft if necessary.

Finally, I would like to ask the authors whether they have considered using cerebrospinal fluid drainage in conjunction with their recommended clamp, cut-and-sew cases? As you know, it is widely accepted to be useful in thoracoabdominal aneurysmectomy. It may well increase safe clamping times and be useful in lowering the incidence of paraplegia when a shunt is not employed.

**Dr Razzouk:** We did not have any specific criteria for the choice of technique, that is, as I mentioned, we changed our practice sometime in the mid 1980s where we decided to do less bypass and stop using the shunts and start using the clamp-and-sew technique. It is still a surgeon’s preference pretty much. The surgeon has to decide what he is comfortable with, depending upon his skill, depending on who is helping, what hour of the day or night it is, or if a perfusionist is available. This paper does not promote any particular technique as superior to another. We are just simply presenting our results. At the same time we are not condemning any other technique. We do not have any experience with the Carmeda heparin-coated circuit. We appreciate the contributions of the University of California, Davis, group in that field and the previous publication. I think this is a great innovation that is going to be very helpful, not only in trauma surgery but also in other types of aortic surgery.

When do we choose to repair primarily? If the tear is partial, most of the time it can be repaired primarily. In our series, one third of the aortic injuries were partial tears. Two thirds were complete transections. Some were just simple clean transections; others were more complicated, complex maceration of the aorta. So if the aortic tissue is pliable, soft, and there is no dissection, we always try to do a primary repair. Remember the aorta was together before the blunt trauma, and most of the patients are young, in their 30s and 40s. The aorta doesn’t have much calcium so it can be brought back together because as you mentioned there are advantages to avoiding a prosthetic graft. We have had 8 injuries to the vocal cord; 3 improved with time, and 5 were permanent.

There is an advantage to waiting before repairing the aorta in a select group of patients who are stable hemodynamically but who have other extrathoracic injuries like major head trauma, severe abdominal injuries, extensive burns, or sepsis; it would be advantageous to wait on those patients if they do not have active aortic bleeding from the chest tube or an expanding hematoma on a CT scan. If you choose to wait on those patients, management including aggressive hemodynamic and radiographic monitoring is essential because some of those patients still die right under your eyes, about 5% of them, if they are not monitored closely. So there is a role for delayed management.

We have had a pseudoaneurysm develop in 2 patients in whom an aortic graft was used for reconstruction. We did not see any pseudoaneurysms in the primary repair group. I think I answered Dr Long’s question about the types of aortic tears. Does the shunt take longer? The shunt always takes longer, and it doesn’t have to do with the extent of injury. It has to do with the false security that it gives the surgeon sometimes that he has all of the time in the world to do the repair while the shunt may or may not be working. I agree with Dr Connolly that the size of the shunt makes a difference. If one is to use the shunt, probably a flow meter should be applied to the shunt to make sure that there is flow in the shunt. The flow in the shunt depends on the cardiac output. If the heart is not working well, you may have a shunt that is not working well either. So you need a flow meter and you need a good size shunt. We did not measure pressure distally in the aorta in those shunt cases; however, in the bypass group we attempted to maintain a flow index of about 1.5 L. We did not use CSF drainage. As you know, most of these patients are done urgently, like I said. They are in the middle of the night, and placing a catheter to drain CSF fluid takes some time. But that is a technique that is useful. We use it in elective thoracoabdominal surgery.

Regarding Dr Schecter’s questions about the patients who exsanguinated in the operating room, 2 of those 3 patients who exsanguinated in the operating room actually belonged to the bypass group and were on cardiopulmonary bypass. In those days, we were heparinizing those patients with a full dose of heparin, and that’s probably part of the reason they exsanguinated.

If a patient develops free rupture of the aortic injury right before your eyes, you really do not have enough time to put them on bypass. Most of the time they have pelvic injuries, abdominal injuries, etc. It’s not that easy to cannulate the femoral vessels; your best bet would be to just clamp as expeditiously as you can, do very little dissection of the aorta, avoid injuring those intercostal arteries, and just do the repair the best you can.