Surgical treatment of acute traumatic rupture of the thoracic aorta: a timing reappraisal?

Thierry Langanay*, Jean-Philippe Verhoye, Hervé Corbineau, Alfonso Agnino, Thierry Derieux, Pascal Menestret, Yves Logeais, Alain Leguerrier

Cardio-vascular and Thoracic Surgery Department, University Hospital Pontchaillou, 2 rue Henri Le Guilloux, 35033 Rennes 09, France

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Abstract

Objective: To report our experience with surgery of thoracic aortic rupture due to blunt trauma. Methods: Between October 1976 and October 1999, 50 patients suffering from acute rupture of the thoracic aorta due to blunt trauma were operated on. On admission, 22 patients (44%) presented with hypovolemic shock and all but five (90%) sustained major associated injuries. Thirty-one patients (62%) underwent immediate operation for aortic repair, whereas the procedure was delayed from 6 to 60 days in ten patients because of late diagnosis or coexisting life-threatening lesions thought to largely worsen the operative risk. In 48 patients, the aortic repair was carried out with the aid of cardiopulmonary bypass (CPB) in order to maintain the distal perfusion and to prevent spinal cord injury. An inert ‘Gott’ shunt and the ‘clamp-and-sew’ technique were used in one patient each. Results: The hospital mortality amounts to 18% (nine patients). Four patients (8%) died intraoperatively and five patients (10%) died in the postoperative course. In five patients (10%) death was caused by cerebral or pulmonary hemorrhage, possibly worsened by systemic heparinization during CPB. One case of postoperative paraplegia (2%) was observed in a patient operated on with the aid of CPB. There was neither aortic rupture nor sudden death in the group of patients in whom the surgical procedure was delayed. Conclusions: The immediate outcome of patients suffering from acute traumatic aortic rupture strongly depends on the associated injuries. In some cases, the emergency aortic repair must be favorably delayed because of the necessity of life-sustaining measures and management of major coexisting injuries, which could be worsened by the use of CPB. Conversely, the risk of paraplegia is significantly reduced by the use of CPB and distal perfusion during the time of aortic cross-clamping. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Aorta; Acute traumatic rupture; Thoracic trauma; Aortic isthmus; Surgery; Cardiopulmonary bypass

1. Introduction

Acute ruptures of the aortic isthmus account for about 85% of aortic injuries due to blunt trauma. They are generally related to a violent crash involving a sudden deceleration. Polytraumatisms and other life-threatening injuries are often associated with the cardiovascular lesions. It is generally admitted that about 80% of the casualties die at the accident scene and that, among the survivors, only 20% would survive without emergency surgical repair of the aortic injury.

After surgery, however, the hospital mortality rate remains high, and stands around 20% in most reports of the literature [1,2]. This high mortality rate seems to be mostly linked to the lesions associated with the aortic rupture. On the other hand, paraplegia is the most fearful complication after surgery requiring aortic cross-clamping. The use of cardiopulmonary bypass (CPB), which provides distal perfusion during aortic cross-clamping appears to dramatically reduce the risk and the actual rate of postoperative spinal cord injury [2]. But the necessity of full systemic heparinization during CPB entails the risk of inducing or severely worsening bleeding in a coexisting internal wound and particularly a brain or pulmonary contusion, leading to fatal hemorrhage in many cases. This raises the difficult question of surgical priority and/or of delaying the aortic repair until the associated life-threatening lesions are sufficiently healed or under control [3,4]. These problems of therapeutic strategy were re-examined and compared to the data of the recent literature throughout the analysis of this series of 50 patients operated on over a 23-year period of time.

2. Patients

From October 1976 to October 1999, 50 patients (40 males and ten females) were operated on for an acute rupture of the thoracic aorta in our institution. Age ranged
between 14 and 58 years with a mean of 28 ± 10.5 years. Thirty-three patients (66%) were less than 30 years old.

The patients’ files were analyzed retrospectively from the data collected at the time of hospitalization. This data together with the data collected during the follow-up were entered into the database of our center, statistically treated with a Hewlett-Packard 9000 computer using the Statview statistical software.

All patients had been victims of a violent accident involving a mechanism of sudden deceleration. Forty-seven patients (94%) experienced a traffic accident: car crash in 36 cases (72%), motorcycle crash in nine (18%), and pedestrian knock over in two (4%). Three patients (6%) had been victims of fall (8–10 m).

On admission, 22 patients (44%) showed evidence of hypovolemic shock with unstable hemodynamics. Ten patients (20%) presented with acute respiratory distress, in connection to a flail chest in six (12%). Five patients (10%) suffered from a pseudocoarctation syndrome with complete abolition of the femoral pulses. In two out of those (4%) there was evidence of ischemia of the lower limbs in relation to a complete thrombosis of the distal aorta.

One patient (2%) had paraplegia due to a coexisting fracture of the rachis and spinal cord lesion, one patient (2%) had paraparesis, and one patient (2%) suffered from neurologic deficit of the right upper limb.

### 3. Diagnosis

The possibility of an aortic rupture was suggested by several signs associated in various manners on standard chest X-rays; widening of the upper mediastinum was present in 41 patients (82%).

In 11 patients (22%) the aortic rupture was suspected because of the loss of parallelism of the aortic walls or the widening of the aortic isthmus at routine computed tomographic (CT) scan performed to check the thoracic lesions of the polytraumatism.

In one patient (2%) the occurrence of a systolic murmur, 11 days after the accident led to suspect the diagnosis which was confirmed by transesophageal echocardiogram (TEE) and subsequent aortogram.

Forty-four patients (88%) underwent an aortogram. In the remaining six patients (12%), aortogram was not carried out either because the CT scan convincingly demonstrated the presence of the aortic lesion (four cases – 8%) or because the clinical condition was too unstable to allow any further delay to surgery. In those two patients, the diagnosis was confirmed at emergency thoracotomy.

The aortic lesion was isolated in only five patients (10%). All other patients (45–90%) sustained major associated injuries, reflecting the magnitude of the violence of the accident. Associated injuries are summarized in Table 1. They were responsible for coma in 11 cases (22%) and emergency laparotomy prior to the aortic repair in 14 cases (28%).

### 4. Surgical treatment

Thirty-one patients (62%) underwent the aortic repair within 24 h after the accident (Fig. 1). Conversely, ten patients (20%) were operated on after a delay extending from 6 to 60 days. This delay was either due to a late diagnosis, the aortic rupture being obscured by major coexisting lesions in 12 patients, or decided on purpose for seven patients because of the presence of severe associated injuries (four polytraumas with multiple and severe orthopedic lesions, one ruptured spleen, one liver wound, and one coma grade III) being thought to make the emergency aortic repair more risky than continued intensive medical therapy.

During surgery, the patients were intubated with a double-lumen tube in order to allow separate ventilation

![Fig. 1. Delay between the accident and the aortic repair.](https://academic.oup.com/ejcts/article-abstract/21/2/282/411597)
of the lungs. The isthmic aorta was approached through a left posterior thoracotomy in the fourth intercostal space in 48 patients (96%). In the remaining two patients, a sternotomy was carried out for resuscitation purpose. Spinal cord protection and distal organs perfusion were achieved by the use of a conventional CPB whenever possible. This was the case in 48 patients (96%), the remaining two patients being operated on either with a ‘Gott’ shunt or the ‘clamp-and-sew’ technique. The CPB was established in various manners. They are summarized in Table 2. The aortic clamping time ranged from 21 to 110 min (mean: 58 min). There was no difference in clamping time according to the presence or absence of CPB.

In two cases (4%) the aortic repair had to be carried out during circulatory arrest at deep hypothermia because of the proximal extension of the aortic tear to the transverse arch. The aortic rupture was circumferential in 33 patients (66%), partial in 16 (32%), and bifocal in one (2%). The aortic repair could be achieved through direct suture in 18 patients (36%) but required a Dacron® prosthesis interposition in the remaining 32 patients (64%).

5. Results

The overall hospital mortality amounts to 18% (nine patients). Four patients died in the operating theatre. Five patients died during the postoperative course. The time, circumstances, and causes of death are summarized in Table 3.

Several non-fatal complications were observed during the postoperative course. In particular, one patient experienced paraplegia (T-3 level) totally regressive within 3 months. Eleven survivors (22%) showed evidence of arterial hypertension. The mean age of this sub-group of patients is 22.7 ± 6.4 years and all but two ruptures were treated by a dacron tube interposition. No particular reason could be found except in one patient in whom a stenosis of the anastomotic site was documented. This patient was later treated surgically by implantation of an aorto-aortic prothetic bypass. In the remaining patients the arterial hypertension was controlled by medical therapy.

6. Discussion

Parmley et al. [5] have reported in their classic autopsy study that 89.7% of patients who sustain a traumatic rupture of the thoracic aorta, will die within 6 h following the accident and that only 9% will survive beyond 24 h. Since 1958, traumatic aortic rupture has been considered as an absolute surgical emergency and the fear of ‘impending rupture’ has led the surgical community to rush for the aortic repair. It appeared with time and through increasing reported experiences that this surgical attitude could be disputed, as it could be in some instances, more harmful than useful. Many reports, indeed, have demonstrated that the aortic lesion is seldom isolated [6,7]. In a study by Pate et al., only two out of 59 patients had an isolated rupture of the thoracic aorta [7]. The authors questioned the conclusions of Parmley et al. emphasizing the fact that it was a retrospective necropsic study implying many selection biases. Similarly, Williams et al. [8] considered that Parmley et al. have overestimated the risk of delayed rupture of the aorta and that many patients could undergo laparotomy or orthopedic surgery prior to the aortic repair with very little risk of sudden rupture of the aortic false aneurysm. In a study concerning 33 cases of isthmic aortic rupture, Cernaianu et al. [9] have

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**Table 2**

<table>
<thead>
<tr>
<th>Techniques of distal perfusion used during aortic repair</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPB</td>
<td>48</td>
<td>96</td>
</tr>
<tr>
<td>Femoral vein–femoral artery</td>
<td>23</td>
<td>46</td>
</tr>
<tr>
<td>Pulmonary artery–femoral artery</td>
<td>21</td>
<td>42</td>
</tr>
<tr>
<td>Pulmonary artery–descending aorta</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Right atrium–femoral artery</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Gott shunt</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

**Table 3**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Associated lesions</th>
<th>Dates</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 OR</td>
<td>5th day</td>
<td>Brain contusion</td>
<td>D0</td>
</tr>
<tr>
<td>2 OR</td>
<td>11th day</td>
<td>Lung contusion</td>
<td>D0</td>
</tr>
<tr>
<td>3 OR</td>
<td>Emergency</td>
<td>Resuscitation</td>
<td>D0</td>
</tr>
<tr>
<td>4 OR</td>
<td>Emergency</td>
<td>Lung contusion</td>
<td>D0</td>
</tr>
<tr>
<td>5 ICU</td>
<td>Emergency</td>
<td>Brain contusion</td>
<td>D1</td>
</tr>
<tr>
<td>6 ICU</td>
<td>Emergency</td>
<td>Distal malperfusion</td>
<td>D1</td>
</tr>
<tr>
<td>7 ICU</td>
<td>2nd day</td>
<td>Distal malperfusion</td>
<td>D2</td>
</tr>
<tr>
<td>8 ICU</td>
<td>Emergency</td>
<td>Preoperative inhalation</td>
<td>D2</td>
</tr>
<tr>
<td>9 ICU</td>
<td>Emergency</td>
<td>Bronchial rupture, Lung contusion</td>
<td>D10</td>
</tr>
</tbody>
</table>

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*OR, operating room; ICU, intensive care unit; ARDS, acute respiratory distress syndrome.*
demonstrated a close relation between the patients’ survival rate and the delay separating the accident and the hospital referral. Conversely, they were unable to establish any relation between the survival rate and the delay separating the hospitalization from the diagnosis, on one hand, and the diagnosis from the aortic repair, on the other.

On the contrary, according to the literature, associated lesions are responsible for the hospital mortality in a majority of cases (Table 4). This stems from four main reasons:

The coexisting lesion can be life-threatening in itself (for instance: spleen rupture, liver contusion, brain trauma, etc).

The number and gravity of the coexisting lesions may induce an untractable condition of hypovolemic shock and multiorgan failure.

The full systemic heparinization required by the CPB may adversely affect a brain or pulmonary contusion leading to fatal hemorrhage.

Some lesions (open fractures, voluminous limbs hematomas) may become septic.

The hospital mortality rate of 18% observed in our experience compares favorably with several studies of recent literature [9–11] which report mortality rates ranging from 5 to 35% and is in accordance with the figures reported by Von Oppell et al. in their meta-analysis [2].

The prevalence and gravity of the lesions associated with the aortic rupture (Table 1) are also in accordance with the data recently published. It is worth noting that no patient died from hemorrhage. On the other hand, five deaths (55%) were directly related to an associated lesion possibly worsened by full heparinization during CPB: two cases of intracerebral hematoma following a major head injury, and three cases of respiratory distress syndrome after lung contusion or inhalation.

Conversely, 19 patients have been operated on more than 24 h after the accident and ten patients beyond a delay exceeding 5 days. No deaths from aortic rupture were observed in this group of 19 patients.

Paraplegia may complicate the surgical repair in 3 to 33% of cases according to the literature [2,11–13]. If we consider the four patients who died in the operating theater and whose neurological status remained unknown, only one of our patients (2%) experienced a regressive paraplegia, appearing 24 h after the surgical procedure. This patient had been operated on with the aid of CPB with a cross-clamping time of 59 min, a mean distal arterial pressure of 80 mmHg during CPB, and a total blood loss of 450 ml for the first postoperative 24 h. The only deleterious element could have been the intraoperative suppression of two pairs of intercostal arteries. On the contrary, this delayed spinal cord injury, might have been the result of some reperfusion syndrome with spinal cord edema. This could then explain the total regression of the neurologic deficit in a rather short time.

In a well-known meta-analysis, carried out from 87 reports and including 1492 patients operated on for acute traumatic rupture of the aorta, Von Oppell et al. [2] compared the rates of hospital mortality and paraplegia according to the surgical technique used during the aortic repair (Table 5). When a distal perfusion system was used, the risk of paraplegia decreased significantly compared to the simple aortic cross-clamping technique (6.1 vs. 19.2%, \( P < 0.0001 \)). The difference between ‘active’ vs. ‘passive’ perfusion systems also appeared significant (2.3 vs. 11.1% paraplegias).

Similar data have been reported by several groups. From a review of the literature including 749 patients, Zeiger et al. [14] observed 2.9% paraplegias with the use of CPB vs. 20.4% with simple cross-clamping. Kodali et al. [10] reported a difference of 3.2 vs. 28.5% and Pate [7] a difference of 3.8 vs. 26.7%.

On the contrary, the use of CPB either total or partial, requiring full heparinization of the patient, has been held responsible for an increase in mortality and morbidity. In particular, this technique can induce fatal hemorrhage of brain and pulmonary contusions. This possibly explains the overmortality observed in the group of patients operated on with total heparinization (18.2%) compared to those operated without heparin (11.9%, \( P < 0.01 \)) in the meta-

<table>
<thead>
<tr>
<th>Authors</th>
<th>Number of aortic ruptures</th>
<th>Total number of deaths</th>
<th>Deaths related to associated lesions</th>
<th>% of deaths related to associated lesions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Katz et al. [12]</td>
<td>35</td>
<td>5</td>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>Mattox et al. [11]</td>
<td>32</td>
<td>6</td>
<td>6</td>
<td>100</td>
</tr>
<tr>
<td>Pate et al. [7]</td>
<td>59</td>
<td>6</td>
<td>2</td>
<td>33</td>
</tr>
<tr>
<td>Rennes</td>
<td>50</td>
<td>9</td>
<td>5</td>
<td>55</td>
</tr>
</tbody>
</table>

Table 5
Comparison of mortality and paraplegia rates according to the method of operative repair (from Ref. [2])

<table>
<thead>
<tr>
<th>Method</th>
<th>Number of patients</th>
<th>Mortality (%)</th>
<th>Paraplegia (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clamp-and-sew</td>
<td>443</td>
<td>16</td>
<td>19.2</td>
</tr>
<tr>
<td>Total distal perfusion</td>
<td>985</td>
<td>15</td>
<td>6.1</td>
</tr>
<tr>
<td>Passive</td>
<td>424</td>
<td>12.3</td>
<td>11.1</td>
</tr>
<tr>
<td>Active</td>
<td>561</td>
<td>17.1</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Table 4
Role of associated lesions in hospital mortality (from literature)
analysis of Von Oppell et al. [2]. In 1985, Mattox et al. [11] had recommended the technique of simple aortic cross-clamping without any adjunct for intraoperative management of the traumatic injury of the descending aorta. In their series, the rate of paraplegia was not significantly different whether CPB was used or not (4.5 vs. 8.3%, respectively). This had led many surgeons to believe that they could avoid using CPB and to consider that the ‘clamp-and-sew’ technique was as safe as the distal perfusion technique. However, Katz et al. [12] have demonstrated that beyond 30 min of cross-clamping duration without distal perfusion, the risk of spinal cord injury dramatically increases. Therefore, considering the very significant differences in the rate of paraplegia highlighted by many authors, there is presently an obvious trend within the surgical community to clearly advocate the use of active distal perfusion systems during the time of aortic repair for acute traumatic isthmic rupture [15,16].

To reduce the conflict between the necessary use of distal perfusion and the increased risk linked to heparinization, it has been recommended to use heparinless bypass systems with a centrifugal pump [2]. Heparin-coated circuits could also represent a tempting alternative as they make theoretically possible the reduction or the suppression of total heparinization. But those systems are still on evaluation and the possible risk of thrombosis entailed by the circuits limits their indications and makes their use still controversial.

Recently, the use of endovascular prosthesis, implanted through the femoral artery, has been proposed [17]. They seem to constitute a promising alternative to surgery, as they have proved to be safe and efficacious in preliminary studies. But the series are still very limited and require to be confirmed by larger experiences.

The concept of pharmacological treatment and medical support of acute aortic dissection introduced by Wheat et al. in 1965 [18] had been first proposed by Aronstam et al. [19] for the treatment of traumatic rupture of the aorta. This attitude was confirmed by several groups in the ensuing years [20,21]. Walker and Pate [22] in an extensive review of the literature found 64 patients medically treated in waiting for aortic surgery. Stulz et al. in 1991 [23] did not observe any death among patients treated in a conservative manner. The good results associated with the overmortality due to the coexisting lesions have led many surgeons to question the dogma of ‘no-delay’ emergency aortic repair in any case and to redefine the therapeutic priorities. Therefore, new strategies have been recently reported for the medical and surgical management of traumatic rupture of the aorta [3,4,16,23–26]. Even if most of these authors have reported no death while waiting for the aortic repair, one cannot consider that there is no risk as Maggisano et al. [26] reported two deaths as a result of aortic rupture within 72 h of admission in the ICU. Fortunately, this seems to be very rare because except in cases of complete rupture the adventitia and surrounding mediastinal structures may form a solid fibrous wall reducing the risk of delayed rupture [22,24,25]. Personally, we are convinced that the best chance of the patients is based on first treating surgically the most life-threatening lesion. The aortic repair will be undertaken immediately if the aortic rupture is isolated or associated with a non-life-threatening lesion. In case of severe life-threatening associated lesion with a stable aortic lesion, the aortic repair will be performed in the second stage after treatment or healing of the coexisting lesion. In this case, the patient will be maintained in a surgical ICU, the aortic evolution being closely monitored by CT scan or TEE under strict control of blood pressure and aortic wall stress through the use of beta-blocking therapy. In case of unstable aortic lesion (for instance, recurring left hemothorax or pseudocoarctation syndrome), requiring an emergency repair despite the presence of severe associated lesions, the aortic repair should be carried out with the use

Fig. 2. Algorithm representing our present therapeutic strategy.
of heparinless systems such as centrifugal pumps and not by using the ‘clamp-and-sew technique’. This policy is summarized in Fig. 2.

With regard to the aortic repair itself, a direct end-to-end suture represents an ideal operation offering the patient a complete anatomic restitution. However, graft interposition is often necessary, as it was in the majority of cases of our series (32 out of 50 patients – 64%). This is particularly true during delayed surgery or in the presence of deeply damaged aortic tissues.

7. Conclusions

This retrospective study is in accordance with the recent reports in literature. It demonstrates that acute traumatic rupture of the thoracic aorta is, indeed, a life-threatening lesion, which deserves surgical repair. It is, however, generally associated with other severe life-threatening lesions and may be hidden among those. It, therefore, justifies early, active, exhaustive diagnostic procedures in case of polytrauma. Should the patient show evidence of impending rupture or major distal malperfusion, the emergency surgical repair is mandatory. But in some instances, the surgical treatment of the aortic rupture must be delayed under strict monitoring. This attitude allows management of other severe life-threatening lesions, which otherwise would deeply increase the risk of the aortic repair, and is responsible for the major part of hospital mortality in those patients. Whatever the circumstances of surgery, distal perfusion downstream the aortic cross-clamping must be maintained, using either CPB or a heparinless centrifugal pump.

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References