ORIGINAL ARTICLE

Total Circulatory Arrest for the Replacement of the Descending and Thoracoabdominal Aorta

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Hypothesis: Hypothermic total circulatory arrest (TCA) in the resection and replacement of the thoracoabdominal and descending thoracic aorta is safe, will significantly decrease the incidence of postoperative renal failure, and should be preferentially performed over left heart bypass (LHB).

Design: Retrospective review case series.

Setting: Large, private, urban teaching hospital.

Patients: All adult patients with aortic disease that involved the distal aortic arch, the descending thoracic aorta, or the thoracoabdominal aorta who underwent resection and graft replacement of the diseased segment via LHB or TCA at our institution from 1989 to 2001 are included in this study. A total of 59 patients were evaluated: 10 had descending thoracic aneurysms, 20 had thoracoabdominal aneurysms, 22 had chronic type B dissections, 4 had acute type B dissections, and 3 had adult coarctations.

Interventions: In 1989 to 1994, LHB was primarily used; in 1994 to 2001, TCA was primarily used.

Main Outcome Measures: Renal failure, 30-day operative mortality, paraplegia, and any other morbidities.

Results: A significant decrease occurred in the incidence of postoperative renal failure from 15% (3/20) in patients who underwent LHB to 0% (0/39) in patients who underwent TCA ($P=.04$). Furthermore, a significant decrease occurred in the 30-day operative mortality, which decreased from 20% (4/20) in patients who underwent LHB to 5% (2/39) in patients who underwent TCA ($P=.04$). Postoperative paraplegia decreased from 5% (1/20) in patients who underwent LHB to 2.6% (1/39) in patients who underwent TCA ($P>.99$).

Conclusions: Our use of TCA in the resection and replacement of the diseased thoracoabdominal and descending thoracic aorta has produced excellent results. Our patients have experienced no postoperative renal failure and a low 30-day operative mortality. The use of TCA in this patient population is a viable option for surgeons comfortable with the technique.

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Many studies[1-13] have reported the use of profound hypothermic total circulatory arrest (TCA) in the treatment of type A and B aortic dissections and thoracoabdominal aortic aneurysms. The safety and efficacy of hypothermic TCA for the resection of the descending and thoracoabdominal aorta have been well established in recent years.[1,6,9-12,14] Atherosclerosis is a major factor in deciding whether the aorta is amenable to cross-clamping, thus influencing the decision to use profound hypothermic TCA. According to Kouchoukos et al,[12] TCA confers an advantage over clamping and bypass by eliminating the need for proximal aortic manipulation, providing a dry, bloodless field, and decreasing the incidence of paraplegia by hypothermic protection of the spinal cord and central nervous system.[3,6-12,14-16] However, other reported series[5] on TCA have cited an increase in operative mortality compared with left heart bypass (LHB) as the price for a decreased incidence of paraplegia. Most institutions use TCA in the treatment of patients with a diseased aortic arch and/or descending thoracic aorta that is not amenable to aortic cross-clamping.[5,13,15]

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Furthermore, the occurrence of renal failure following surgical repair of thoracoabdominal aortic aneurysms and descending thoracic aortic aneurysms is a topic of significant interest. Studies[5,7,17-19] report the incidence of renal failure that occurs following this surgery as remaining high and having an association with high early and late mortality rates.

The safety and efficacy of hypothermic TCA for the resection of the descending and thoracoabdominal aorta have been reported in recent years. However, compared with the LHB technique, no other reported series on TCA has, to our knowledge, shown elimination of postoperative renal failure, a significantly lower overall 30-day operative mortality, and a trend toward lower postoperative paraplegia. In the present series, we sought to compare the morbidity and mortality associated with replacement of the descending and thoracoabdominal aorta using elective TCA vs LHB performed at our institution.

METHODS

All adult patients with aortic disease that involved the distal aortic arch, the descending thoracic aorta, or the thoracoabdominal aorta who underwent resection and graft replacement of the diseased segment via LHB or TCA at Cedars-Sinai Medical Center, Los Angeles, Calif, between January 1989 and October 2001 are included in this study. From 1989 to 1994, LHB was primarily used, whereas from 1994 to 2001, elective TCA was primarily used. Since 1994 we have adopted the routine implementation of TCA for all of our thoracic aortic operations, unless otherwise contraindicated, as in the case of traumatic aortic injury. In total, 59 patients underwent repair: 10 for descending aneurysms, 20 for thoracoabdominal aneurysms, 22 for chronic type B dissections, 4 for acute type B dissections, and 3 for adult coarctations. The total numbers and the breakdown for each type of aortic disease treated are given in **Table 1**. The clinical characteristics and comorbidities, which were similar between the 2 groups, are given in **Table 2**. Statistical analysis was performed using the Fisher exact and χ^2 tests.

Table 1. Types of Aortic Disease Treated

Type of Aortic Disease	LHB (n = 20)	TCA (n = 39)
Descending aneurysm	2	8
Thoracoabdominal aneurysm	8	12
Chronic type B dissection	6	16
Acute type B dissection	2	2
Coarctation	2	1

Abbreviations: LHB, left heart bypass; TCA, total circulatory arrest.

Table 2. Clinical Characteristics and Comorbidities of the 2 Groups

Comorbidities	TCA (n = 39)	LHB (n = 20)
Hypertension	35	18
History of smoking	27	7
Coronary artery disease	10	5
Peripheral vascular disease	10	8
Diabetes mellitus	4	4
Marfan syndrome	1	2
Prior proximal aorta repair	2	0
Prior coarctation repair	1	1
Prior distal aorta repair	1	0
Prior abdominal aorta repair	5	2
Prior CABG or TCA or stent placement	9	2

Abbreviations: CABG, coronary artery bypass graft; LHB, left heart bypass; TCA, total circulatory arrest.

RESULTS

TCA TIMES

The TCA times for the different diagnoses encountered ranged from an average of 46.0 minutes for acute type B dissections to an average of 35.0 minutes for coarctation of the aorta (**Table 3**).

MORTALITY

A statistically significant difference in mortality occurred between the 2 groups. The overall 30-day mortality rate for patients undergoing surgery via TCA was 5% (2/39) and stayed the same for the hospital mortality. This is in contrast to patients who underwent LHB, who had a 30-day mortality of 20% (4/20) ($P = .04$) (**Figure 1**). In the TCA group, 2 deaths occurred. One patient with a descending thoracic aneurysm died intraoperatively of pump failure, subsequent to rupture and hemorrhage. Another patient in the TCA group, who had a thoracoabdominal aneurysm, died on the fifth postoperative day subsequent to multiorgan failure. In the LHB group, 4 deaths occurred: 2 patients with chronic type B dissections and 2 with thoracoabdominal aneurysms. In the 2 patients with chronic type B dissections, one died intraoperatively due to pump failure subsequent to arrhythmia (ventricular tachycardia/fibrillation), whereas the other patient (who had a chronic type B dissection) died on the first postoperative day due to arrhythmia (ventricular tachycardia/fibrillation). Of the 2 patients with thoracoabdominal aneurysms, one died on the 18th postoperative day subsequent to hemorrhage, whereas the other died on the 20th postoperative day subsequent to renal failure.

NEUROLOGIC COMPLICATIONS

No significant difference in neurologic complications between the 2 groups was observed. Paraplegia occurred in 1 (3%) of 39 patients undergoing surgery via TCA compared with 1 (5%) of 20 patients undergoing LHB ($P > .99$) (**Figure 2**). The patient undergoing surgery via TCA had a chronic type B dissection, whereas the patient undergoing surgery via LHB had an acute type B dissection. Postoperative hemiparesis, with return to normal neurologic function before discharge, was found in 3 (8%) of 39 patients undergoing surgery via TCA and in 1 (5%) of 20 patients undergoing LHB ($P > .99$). Stroke with a resulting focal neurologic deficit occurred in 4 (10%) of the 39 patients undergoing TCA vs 1 (5%) of the 20 patients undergoing LHB ($P = .65$). Interestingly, among the

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Table 3. TCA Times for All Aortic Diseases Treated by TCA

Type of Aortic Disease	Average (Range) Time in TCA Group, min		Average (Range) Time in LHB Group, min	
	TCA	CPB	TCA	CPB
Descending aneurysm	35.8 (16-51)	149.5 (100-178)	Not used	58.5 (35-82)
Thoracoabdominal aneurysm	36.6 (5-57)	179.7 (134-235)	Not used	59.7 (36-102)
Chronic type B	43.1 (29-59)	155.5 (100-206)	Not used	101.8 (70-134)
Acute type B	46.0 (35-57)	127.5 (121-134)	Not used	Unavailable
Coarctation	35.0 (35)	Unavailable	Not used	0.0 (No CPB used)

Abbreviations: CPB, cardiopulmonary bypass; LHB, left heart bypass; TCA, total circulatory arrest.

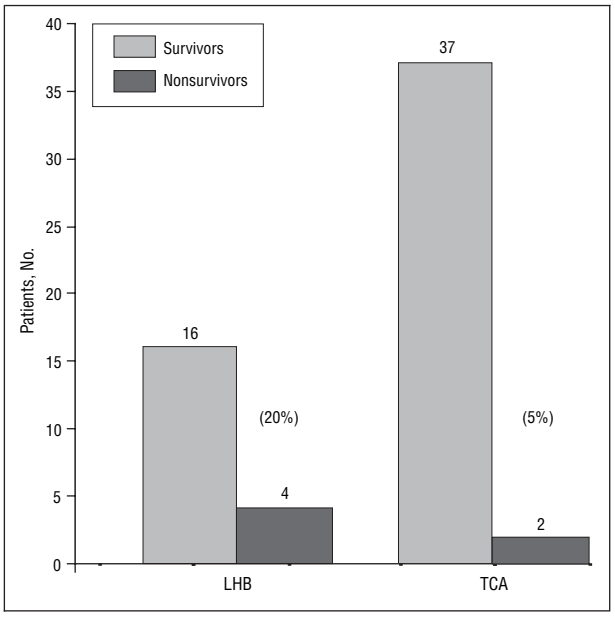

Figure 1. Thirty-day operative mortality decreased from 20% (4/20) with left heart bypass (LHB) to 5% (2/39) with total circulatory arrest (TCA) (P=.04).

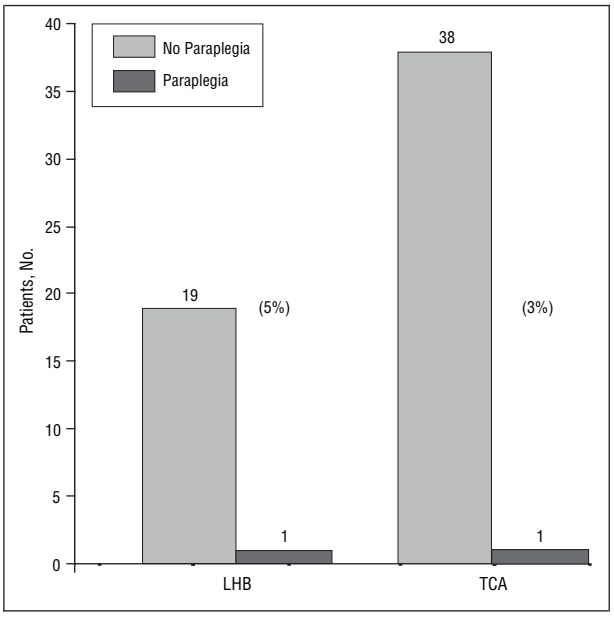

Figure 2. Postoperative paraplegia decreased from 5% (1/20) with left heart bypass (LHB) to 3% (1/39) with total circulatory arrest (TCA) (P>.99).

patients undergoing surgery via TCA with neurologic sequelae, all had chronic type B dissections. The one patient who suffered neurologic complications in the LHB group had a thoracoabdominal aneurysm.

PULMONARY DYSFUNCTION

No significant difference was noted between the 2 groups with respect to pulmonary dysfunction. Respiratory failure that required prolonged (>48 hours) mechanical ventilation was required in 6 (15%) of the 39 patients undergoing TCA, whereas 4 (20%) of the 20 patients undergoing LHB required prolonged ventilatory support (P=.72). Tracheostomy was required in 4 (10%) of the 39 patients undergoing TCA and in 2 (10%) of the 20 patients in the LHB group (P>.99).

RENAL DYSFUNCTION

Renal failure with resultant elevated creatinine levels occurred in no patients undergoing TCA in contrast to 3 (15%) of the 20 patients in the LHB group (P=.04) (**Figure 3**). Postoperative renal dysfunction was defined as a creatinine level 1.5 times the preoperative level or higher.

COMMENT

The decision to use TCA depends on a number of factors. Most studies that evaluate TCA report the use of this technique only in select cases and do not use TCA as their routine approach in the resection of the distal aortic arch and descending thoracic aortic dissections or thoracoabdominal aneurysms. In fact, it is usually considered the exception rather than the common practice for most surgeons.

Often TCA is used when the patient is deemed at high risk for potential neurologic complications, such as the risk of paraplegia from spinal cord ischemic injury in patients with extensive descending thoracic aortic aneurysms or in patients with Crawford type I, II, or III thoracoabdominal aortic aneurysms.[9-12] Certainly, another circumstance that calls for the use of TCA is the presence of atherosclerosis, where the patient's aorta is severely calcified and cannot be safely cross-clamped for

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fear of possible embolic complications and stroke.[13,15] Also, the issues of renal failure and mortality following TCA, compared with other techniques, are controversial and important topics with respect to thoracic and thoracoabdominal aortic repair. Some studies[5,18] have suggested that the rate of renal failure remains high following these procedures and that it may even have an association with increased mortality in this patient population.

We reviewed our results for all operations performed on the distal aortic arch, descending thoracic aorta, and thoracoabdominal aorta at our institution. We compared outcomes between our previous technique of LHB from 1989 to 1994 and results after our switch to the routine use of profound hypothermic TCA from 1994 to 2001 for the same conditions. Although our 2 study groups are separated by almost a decade, we believe this comparison provides useful information regarding the safety and efficacy of our technique.

Profound hypothermic TCA has been used by many surgeons for a variety of conditions. Its use has often been described in the replacement of the aortic arch, descending thoracic aorta, and thoracoabdominal aorta.[5,10,12,17,19-24] In addition, other authors[2-4,8-14,16] have reported extensively on the use of hypothermic TCA and the advantages conferred by this technique.

Debate exists over mortality associated with the use TCA. Some studies, such as the one by Safi et al,[5] cite a higher mortality rate associated with the use of hypothermic TCA, whereas other studies note a decreased mortality rate[10-12] or at least no increase or difference in mortality with or without the use of TCA.[1] In our series, we found a significant difference in mortality between the TCA and LHB groups, with patients undergoing TCA having a mortality rate of only 5% compared with 20% in patients undergoing LHB.

Hypothermia has been shown to increase the tolerance of neurologic tissue to ischemia, namely, a decrease in spinal cord susceptibility to ischemic damage and paralysis.[3,7,9,14-16] This added protection and increased duration of tolerable spinal cord ischemia conferred by hypothermia allows for more time to reimplant lumbar and intercostal vessels. The profound hypothermia also provides protection for the brain, with decreased cerebral ischemic injury.[12] Our study did not show a significant difference between TCA and LHB with respect to neurologic sequelae.

A notable benefit provided by TCA in addition to brain and spinal cord protection is the added protection of the kidneys and abdominal viscera in the surgical repair of the aortic arch and descending thoracic aortic dissections and thoracoabdominal aortic aneurysms.[10-12] Some studies[18] have not shown an improvement in renal protection with the use of TCA and report the incidence of renal failure that occurs with this surgery as remaining high and having an association with high early and late mortality rates.

The use of TCA in our study completely eliminated the incidence of postoperative renal failure. The difference in renal failure was statistically significant between the 2 groups, with a 0% rate of renal failure in patients undergoing TCA compared with a 15% rate of renal failure with LHB ($P = .04$).

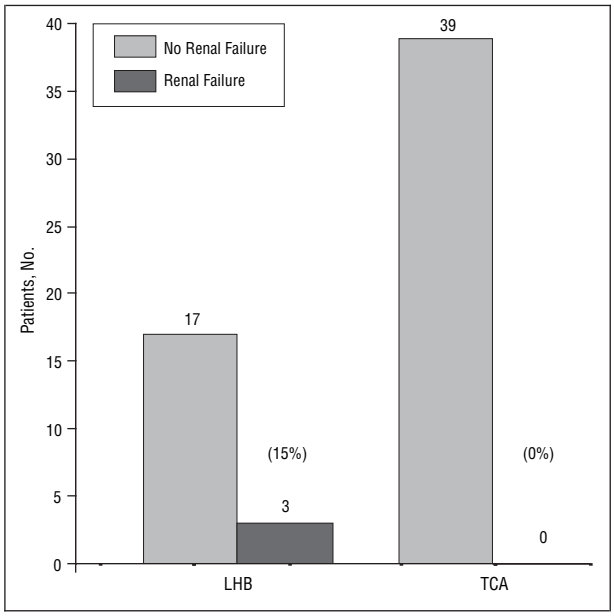

Figure 3. The incidence of postoperative renal failure decreased from 15% (3/20) with left heart bypass (LHB) to 0% (0/39) with total circulatory arrest (TCA) ($P = .04$).

In summary, this single institution comparison of results between profound hypothermic TCA and LHB techniques provides useful information regarding the safety and efficacy of our technique in the resection of the distal aortic arch, descending thoracic aortic dissections, and thoracoabdominal aneurysms. We observed that the use of TCA in the resection of the distal aortic arch and descending and thoracoabdominal aorta has eliminated renal failure and significantly decreased the 30-day operative mortality. Furthermore, we observed no difference in neurologic outcomes even though we did not use additional adjuncts for spinal cord protection in patients undergoing TCA. We recommend the routine use of TCA and believe that this technique is safe, has good results, and should be used for patients who require distal aortic arch and descending and thoracoabdominal aortic surgery.

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REFERENCES

1. Rokkas CK, Kouchoukos NT. Single-stage extensive replacement of the thoracic aorta: the arch-first technique. *J Thorac Cardiovasc Surg*. 1999;117:99-105.
2. Lai DT, Robbins RC, Mitchell RS, et al. Does profound hypothermic circulatory arrest improve survival in patients with acute type A aortic dissection? *Circulation*. 2002;106(suppl 1):I218-I228.
3. Kouchoukos NT, Rokkas CK. Hypothermic cardiopulmonary bypass for spinal cord protection: rationale and clinical results. *Ann Thorac Surg*. 1999;67:1940-1958.

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4. Kouchoukos NT, Masetti P, Rokkas CK, Murphy SF. Single-stage reoperative repair of chronic type A aortic dissection by means of the arch-first technique. *J Thorac Cardiovasc Surg*. 2001;122:578-582.
5. Safi HJ, Miller CC III, Subramaniam MH, et al. Thoracic and thoracoabdominal aortic aneurysm repair using cardiopulmonary bypass, profound hypothermia, and circulatory arrest via left side of the chest incision. *J Vasc Surg*. 1998; 28:591-598.
6. Bavaria JE, Pochettino A, Brinster DR, et al. New paradigms and improved results for the surgical treatment of acute type A dissection. *Ann Surg*. 2001; 234:336-343.
7. Di Eusanio M, Wesselink RM, Morshuis WJ, Dossche KM, Schepens MA. Deep hypothermic circulatory arrest and antegrade selective cerebral perfusion during ascending aorta-hemiarch replacement: a retrospective comparative study. *J Thorac Cardiovasc Surg*. 2003;125:849-854.
8. Rokkas CK, Cronin CS, Nitta T, et al. Profound systemic hypothermia inhibits the release of neurotransmitter amino acids in spinal cord ischemia. *J Thorac Cardiovasc Surg*. 1995;110:27-35.
9. Kouchoukos NT, Wareing TH, Izumoto H, Klausing W, Abboud N. Elective hypothermic cardiopulmonary bypass and circulatory arrest for spinal cord protection during operations on the thoracoabdominal aorta. *J Thorac Cardiovasc Surg*. 1990;99:659-664.
10. Kouchoukos NT, Masetti P, Rokkas CK, Murphy SF, Blackstone EH. Safety and efficacy of hypothermic cardiopulmonary bypass and circulatory arrest for operations on the descending thoracic and thoracoabdominal aorta. *Ann Thorac Surg*. 2001;72:699-708.
11. Kouchoukos NT, Masetti P, Rokkas CK, Murphy SF. Hypothermic cardiopulmonary bypass and circulatory arrest for operations on the descending thoracic and thoracoabdominal aorta. *Ann Thorac Surg*. 2002;74:S1885-S1898.
12. Kouchoukos NT, Daily BB, Rokkas CK, Murphy SF, Bauer S, Abboud N. Hypothermic bypass and circulatory arrest for operations on the descending thoracic and thoracoabdominal aorta. *Ann Thorac Surg*. 1995;60:67-77.
13. Davila-Roman VG, Murphy SF, Nickerson NJ, Kouchoukos NT, Schechtman KB, Barzilai B. Atherosclerosis of the ascending aorta is an independent predictor of long-term neurologic events and mortality. *J Am Coll Cardiol*. 1999;33:1308-1316.
14. Kouchoukos NT, Daily BB, Wareing TH, Murphy SF. Hypothermic circulatory arrest for cerebral protection during combined carotid and cardiac surgery in patients with bilateral carotid artery disease. *Ann Surg*. 1994;219:699-706.
15. Goldstein LJ, Davies RR, Rizzo JA, et al. Stroke in surgery of the thoracic aorta: incidence, impact, etiology, and prevention. *J Thorac Cardiovasc Surg*. 2001; 122:935-945.
16. Rokkas CK, Sundaresan S, Shuman TA, et al. Profound systemic hypothermia protects the spinal cord in a primate model of spinal cord ischemia. *J Thorac Cardiovasc Surg*. 1993;106:1024-1035.
17. Livesay JJ, Cooley DA, Reul GJ, et al. Resection of aortic arch aneurysms: a comparison of hypothermic techniques in 60 patients. *Ann Thorac Surg*. 1983; 36:19-28.
18. Safi HJ, Harlin SA, Miller CC, et al. Predictive factors for acute renal failure in thoracic and thoracoabdominal aortic aneurysm surgery. *J Vasc Surg*. 1996; 24:338-345.
19. Cooper WA, Duarte IG, Thourani VH, et al. Hypothermic circulatory arrest causes multisystem vascular endothelial dysfunction and apoptosis. *Ann Thorac Surg*. 2000;69:696-703.
20. Svensson LG, Crawford ES, Hess KR, et al. Deep hypothermia with circulatory arrest: determinants of stroke and early mortality in 656 patients. *J Thorac Cardiovasc Surg*. 1993;106:19-31.
21. Crawford ES, Coselli JS, Safi HJ. Partial cardiopulmonary bypass, hypothermic circulatory arrest, and posterolateral exposure for thoracic aortic aneurysm operation. *J Thorac Cardiovasc Surg*. 1987;94:824-827.
22. Coselli JS. Thoracoabdominal aortic aneurysms: experience with 372 patients. *J Card Surg*. 1994;9:638-647.
23. Griepp RB, Stinson EB, Hollingsworth JF, Buehler D. Prosthetic replacement of the aortic arch. *J Thorac Cardiovasc Surg*. 1975;70:1051-1063.
24. Coselli JS, Crawford ES, Beall AC Jr, Mizrahi EM, Hess KR, Patel VM. Determination of brain temperatures for safe circulatory arrest during cardiovascular operation. *Ann Thorac Surg*. 1988;45:638-642.

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