Management of the Left Subclavian Artery during Endovascular Stent Grafting for Traumatic Aortic Injury – A Systematic Review

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Abstract
Objectives and design: Traumatic thoracic aortic injuries are serious and may be associated with high morbidity and mortality. Endovascular stent grafting is now an established treatment option which often requires proximal landing zone extension through left subclavian artery (LSA) origin coverage. This in turn can lead to downstream ischaemic complications which may be lessened by LSA revascularisation. This study investigates the consequence of LSA coverage and potential benefit of revascularisation.

Materials and methods: Systematic literature review of studies between 1997 and 2010 identified 94 studies incorporating 1704 patients. Chronological trends in LSA management practice for trauma were sought. Designated outcomes of interest were prevalences of left arm ischaemia, stroke, spinal cord ischaemia, endoleak, stent migration, need for additional procedure and mortality. These outcomes were compared in patients with and without LSA coverage (taking account of the degree of coverage). The impact of revascularisation on these outcomes was also explored. Statistical analysis included examination with Chi-Square or Fisher’s tests as appropriate.

Results: Isolated total LSA coverage without revascularisation increases the prevalence of left arm ischaemia [prevalence of 4.06% versus 0.0% (p < 0.001)]; stroke [prevalence of 1.19% versus 0.23% (p = 0.025)]; and need for additional procedure [prevalence of 2.86% versus 0.86% (p = 0.004)]. In contrast there were no reported cases of stroke, spinal cord ischaemia,
Blunt aortic injury is the second highest cause of post-traumatic death, with the highest mortality occurring early in the first few hours after injury. More than 80% with such trauma die on the accident scene. Thirty percent of those surviving the initial insult go on to die at the hospital, with a third of these patients dying before definitive surgical treatment.

Injury is often associated with rapid deceleration in road traffic accidents or falls, with patients suffering severe multiple trauma including cranio-cerebral trauma, thoracic contusion and rib fractures, intra-abdominal bleeding and bone fractures. Unlike the survivors of penetrating thoracic injuries, patients who sustain blunt aortic injury present with multiple associated injuries, which not only complicate but can also make early surgical intervention unfeasible.

Blunt aortic injury often occurs in the peri-isthmic region of the thoracic aorta, in close proximity to the ligamentum arteriosum and just distal to the origin of the left subclavian artery (LSA). The nature of injury involves shearing or bending stresses, affecting the relatively mobile aortic arch in relation to the fixed descending aorta.

Endovascular stent grafting has provided a less-invasive alternative to open surgical repair for thoracic aortic pathology. Endovascular treatment for aortic disorders was first described by Parodi et al. with the use of a stent graft to treat an abdominal aortic aneurysm, whilst Volodos et al. first described thoracic endovascular stent grafting in 1991, with this minimally invasive technique being especially suitable in high-risk patients with co-morbidities and poly-trauma. Dake et al. were the first group to report on post-traumatic thoracic aorta stent grafting in 1994 with good success.

Stent grafting of the thoracic aorta ideally requires proximal landing zones distal to the LSA and proximal to the mesenteric vessels. There are increasing reports of the use of the aortic arch proximal to the LSA to provide additional length for the proximal landing zone, consequently covering the LSA. This coverage has previously been shown to cause ischaemic complications, such as left arm ischaemia, stroke and spinal cord ischaemia.

Conversely, successful coverage has been described without the development of such complications. Revascularisation of the LSA with either transposition or bypass from the carotid artery has been shown to prevent or treat these complications.

This article aims to: (1) study the prevalence of outcomes in endovascular stent grafting of the thoracic aorta following trauma, assessing the impact of coverage of the LSA and furthermore revascularisation of the LSA, (2) investigate impact of ‘full’ coverage versus ‘partial’ coverage on the outcomes and (3) identify any chronological trend in the practice of LSA management in patients with thoracic aortic trauma.

Materials and Methods

Literature search

The literature search was performed using a predetermined protocol. MEDLINE, Ovid, Embase, Cochrane and the UK National Library for Health databases were searched for all relevant studies up to and including March 2010, using the following MeSH search headings: ‘accidents, traffic’ AND ‘aorta, thoracic/injuries’ OR ‘aorta, thoracic/surgery’ OR subclavian artery/surgery’ AND ‘complications’ OR ‘intra-operative complications’ OR ‘postoperative complications’.

All abstracts resulting from the search were screened. The search was then extended by using the ‘related articles’ function and screening the reference list of those manuscripts identified in the initial search. All full texts were closely reviewed for eligibility to generate the final group of studies.

Data extraction

Two reviewers extracted data from each study according to a predefined protocol. Data extracted included first author; year of publication; study design; number of patients studied; patient population demographics; trauma score used; mechanism of trauma; preoperative investigations; anatomy of aortic trauma (‘isthmus’/’non-isthmus’); aortic dimensions; number of LSA covered separated into ‘full’ and ‘partial’; number of LSA revascularised separated into ‘transposition’ and ‘bypass’; stent graft manufacturer, number and dimensions; complications without LSA coverage; complications with LSA coverage with and without revascularisation; and complications of LSA coverage with ‘full’ and ‘partial’ coverage (Table 1).

Inclusion and exclusion criteria

All studies reporting endovascular stenting for thoracic aortic injury following trauma were included. This was inclusive of all studies reporting LSA coverage with or without revascularisation from which the defined outcomes were extractable.

We excluded all studies in which the defined outcomes were not extractable, were not specifically described for traumatic cases, there was a patient population of less than...
five cases, there was an overlap of the data previously described by the same or a different group and the study was not published in English.

Outcomes

Outcomes included left arm ischaemia (defined as critical arm ischaemia or symptoms of claudication but not an asymptomatic reduction in blood pressure in the left arm); stroke; spinal cord ischaemia (including paraplegia and paraparesis); endoleak (types I–IV); stent migration; the need for additional procedure (either further endovascular procedure, conversion to open procedure or later endovascular or open procedure); non-procedural mortality (30-day mortality of any cause); and procedural mortality (30-day mortality specifically related to the aortic injury or endovascular procedure).

Statistical analysis

Data were classified into three paired groups as follows: no LSA coverage and ‘any’ (partial or full) LSA coverage; partial LSA coverage and full LSA coverage; and ‘any’ LSA coverage with and without revascularisation.

Statistical analysis was carried out using chi-square test with Yates’ correction or Fisher’s two-tailed test (where prevalence was < 5) comparing the total prevalence of outcomes of the above groups.

The tests were performed using the epidemiological software COMPARE Version 1.42 (Epidemiological Perspectives & Innovations, 2004) and statistical significance was achieved at p ≤ 0.05.

Results

The initial MeSH terms search generated 163 studies. A further 2548 studies were identified by expanding the search using the reference lists from these studies and using the ‘related articles’ search function. Of these studies, 94 were found to fulfil our inclusion criteria17–50,51–110 (Fig. 1). The full texts of this final study group were reviewed and data were extracted as per our protocol. Demographic, trauma and stent graft data of the final study group are presented in Table 2. Of the total 1704 patients, the LSA was covered in 25% and revascularised in 8%. Subgroup analysis that analyses the degree of LSA coverage, demonstrated full coverage in 76% and partial coverage in 18%.

No LSA coverage versus LSA coverage (Fig. 2)

Comparison of the outcomes demonstrated a significantly increased prevalence of left arm ischaemia, stroke and the need for an additional procedure in the LSA coverage group (p < 0.001; p = 0.025; p = 0.004, respectively). In the cases of LSA coverage where the LSA was revascularised, there were no observed cases of left arm ischaemia, stroke, spinal cord ischaemia, endoleak or mortality. Overall, there were 21 cases of non-procedural mortality and two cases of procedural mortality in the uncovered group in comparison to two cases of non-procedural mortality and one case of procedural mortality in the LSA coverage group.

LSA partial coverage versus LSA full coverage (Fig. 2)

Whilst there were no statistically significant differences between these groups, there were no reported cases of stroke, spinal cord ischaemia, endoleak, stent migration or mortality with partial coverage of the LSA. There was one reported case of left arm ischaemia and one report of a need for an additional procedure. Noteworthy prevalence of outcomes in the full coverage group were of left arm ischaemia (2.84%, n = 9), endoleak (1.26%, n = 4), the need for an additional procedure (2.21%, n = 7) and mortality (two non-procedural, 0.63%; one procedural, 0.32%).
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LSA revascularisation versus no LSA revascularisation (Fig. 2)

There were no statistically significant differences between these groups; however, in all the literature in the cases where the LSA was covered and revascularised, there were no reports of left arm ischaemia, stroke, spinal cord ischaemia, endoleak or mortality. There was one reported case of stent migration and one report of a need for an additional procedure. Noteworthy prevalence of outcomes in the non-revascularised group were of left arm ischaemia (4.16%, \( n = 16 \)), endoleak (1.56%, \( n = 6 \)), the need for an additional procedure (2.6%, \( n = 10 \)) and non-procedural mortality (1.04%, \( n = 4 \)). There was no procedural mortality reported in this group.

Discussion

There is a high rate of mortality associated with blunt aortic trauma both before and after surgical intervention. Survivors of such trauma require early surgery despite their multiple associated injuries. The minimally invasive nature of endovascular stent grafting has proved to be very suitable for these high-risk poly-trauma patients and has been studied extensively. This procedure can be proven to be quite anatomically challenging in the trauma patient, both due to the proximity of the lesion to the isthmus and due to the possibility of an acutely angulated distal aortic arch, seen in younger patients.\(^{111}\) To overcome these problems and to provide an adequate seal zone, landing zones have been extended to reach proximal to the origin of the LSA, consequently covering the artery. This compromises left upper limb blood supply as well as the vertebral artery, which may have a critical role in the circulation to the posterior cerebral lobe, brainstem, cerebellum and spine.\(^{112}\) There have been conflicting reports of the ischaemic complications resulting from this coverage,\(^{14–16}\) and although surgical revascularisation in the form of either transposition or bypass has been shown to prevent or treat such complications, there is no general consensus regarding the appropriate management of the LSA in this scenario.\(^{17}\)

Our findings in this study have shown that in the context of endovascular stent grafting in blunt aortic trauma coverage of the LSA results in an increased prevalence of left arm ischaemia, stroke and the need for an additional procedure. Interestingly, there was a non-significant reduction in the prevalence of the endoleak and non-procedural mortality in cases where the LSA was covered and this is something that requires further investigation. Comparison of LSA coverage with and without revascularisation surprisingly demonstrated no statistically significant differences; however, there were no recorded cases of left arm ischaemia, stroke, spinal cord ischaemia, endoleak or mortality when the LSA was revascularised, emphasising the significant impact of the revascularisation procedure.

We have also demonstrated that the extent of LSA coverage has an impact on the complication profile. In the cases where the LSA was only partially covered, with or without revascularisation, there were no reported cases of stroke, spinal cord ischaemia, endoleak, stent migration or
mortality. This supports the concept of using the aortic arch as the proximal landing zone for a fenestrated graft, preserving the brachiocephalic and left common carotid arteries. Kurimoto et al. demonstrated no neurological complications including strokes and spinal cord ischaemia in their cohort of trauma patients using fenestrated stent graft without revascularisation of the LSA.18

Time trend analysis of LSA coverage and revascularisation between 1997 and 2009 shows continuous variation. The highest rates of LSA coverage occurred in 1999 at 78%, described solely by Rousseau et al. Using almost exclusively ‘home-made’ fenestrated stent grafts and revascularising one patient post-coverage, they reported no mortality or significant morbidity during follow-up. Despite these promising results, the rate of coverage and revascularisation subsequently decreased. LSA coverage peaked again at 40% in 2003 following publication of successful results by Fattori et al. amongst others. The former used only partial coverage of the LSA and besides one late presentation of endoleak reported, all patients were asymptomatic at follow-up. The rate of revascularisation however did not match the rise in coverage. The latest peak in coverage rate occurred in 2009 at 48% but with only 1.3% of these being revascularised. This followed full coverage of the LSA in 20 patients, and pre-coverage revascularisation in one by Buz et al. This variation in practice reflects the lack of a consensus for LSA management in traumatic aortic injury and shows reliance on recently published data.

There are several limitations to this study. One is the lack of a substantial number of comparative studies looking at the complications of LSA coverage and revascularisation. There are also, of course, no randomised control trials analysing the above-mentioned relationship, meaning that only level-IV evidence is available.

There is also potential for significant clinical heterogeneity in this study due to the data being acquired from numerous international centres involving different patient demographics, operating techniques and skill levels. Another limitation of this study is the lack of detailed data pertaining to the specific subgroups such as full coverage, partial coverage, revascularisation and no revascularisation of the LSA. Many of the studies analysed would report on the total prevalence of the outcomes of interest with no specific or concise reference to the subgroup in which these outcomes occurred. As a result, there is a seeming discrepancy of numbers in our analysis, where, whilst we have included and analysed the total prevalence of the outcomes, we have omitted the equivocal reports not specifically attributed to the subgroups from these sub-analyses.

A further limitation is the absence of a consensus on the type of stenting for LSA management and formal revascularisation guidelines, with mere recommendations that revascularisation should be individualised and addressed expectantly on the basis of anatomy, urgency and the availability of surgical expertise. This has made the procedure of revascularisation institutional-, surgeon- and case-dependent. The timing of revascularisation in relation to presentation is also uncertain which may skew the outcomes of revascularisation. For example, if a patient presents with left arm ischaemia directly as a result of the aortic injury, they may undergo LSA revascularisation...
before the stent-grafting procedure, thereby influencing the post-intervention prevalence of left arm ischaemia, with uncertainty between persistent left arm ischaemia and that of a complication of the intervention.

A final limitation was the absence of risk stratified or adjusted for co-variate data, rendering multivariate analysis not possible.

Conclusions

Coverage of the LSA in endovascular stent grafting of the thoracic aorta after trauma increases the prevalence of left arm ischaemia, stroke, and a need for further intervention. Revascularisation of the LSA may contribute to reducing the prevalence of these complications and despite a lack of statistical significance, thus far there have been no recorded cases of left arm ischaemia, stroke, spinal cord ischaemia, endoleak or mortality where the LSA has been revascularised. Partial or fenestrated coverage of the LSA, with or without revascularisation, has also been shown to have a profound impact on the complication profile of the stent-grafting procedure, and whilst again lacking statistical significance, there were no reported cases of stroke, spinal cord ischaemia, endoleak, stent migration or mortality in this study. These findings highlight the need for further investigation of the outcomes of partial or fenestrated coverage and concurrent revascularisation of the LSA in order to provide a robust and firm management consensus for endovascular stent grafting in traumatic thoracic aortic injury.

Conflict of Interest

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