Eur Spine J (2019) 28:463–469
https://doi.org/10.1007/s00586-017-5364-4

ORIGINAL ARTICLE

Cerebral ischaemia following anterior upper thoracic spinal surgery utilizing a partial manubrial resection

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Received: 8 July 2017 / Revised: 24 August 2017 / Accepted: 21 October 2017 / Published online: 26 October 2017

Abstract
Purpose Firstly, to describe two cases of cerebral ischaemia complicating anterior upper thoracic spinal surgery and define the likely cause of this complication. Secondly, to describe preventative measures and the effect these have had in reducing this complication within our institution.
Methods Firstly, a review of two cases of cerebral ischaemia complicating anterior upper thoracic spinal surgery utilizing a partial manubrial resection. Secondly, cadaveric dissections of the carotid arteries to determine the effect of neck positioning and aortic arch retraction during a simulated procedure. Thirdly, a retrospective review of 65 consecutive cases undergoing this procedure and assessment of the rate of this complication before and after the adoption of preventative measures.
Results Two cases of carotid artery territory cerebral ischaemia, without radiographic evidence of carotid or cardiac pathology were identified in 50 consecutive cases prior to the implementation of preventative measures. These patients revealed fluctuating hemodynamic instability after placement of the inferior retractor. Cadaveric dissection reveals significant carotid artery traction particularly with neck extension. Since the adoption of preventative measures, no cases of cerebral ischaemia have been encountered.
Conclusions Cerebral ischaemia is a potential complication of anterior upper thoracic spinal surgery requiring retraction of the aortic arch. This most likely occurs from carotid stenosis due to aortic retraction and therefore, may be reduced by positioning the patient with neck flexion. Continuous non-invasive monitoring of cerebral saturation, as well as actively monitoring for hemodynamic instability and reduced carotid pulsation after retractor placement, allows for early detection of this complication. If detected, perfusion can be easily restored by reducing the retraction of aortic arch.

Keywords Cerebral ischaemia · Thoracic spine · Spinal metastases · Anterior thoracic · Carotid artery · Corpectomy · Upper thoracic

Introduction

Spinal metastases are common and affect more than 36% of patients dying from neoplastic disease [1]. The cervicothoracic junction and upper thoracic spine are commonly involved and represent a challenging location for surgical resection and stabilization. A posterior approach is more familiar for most surgeons; however, most metastases are anterior and thus tumor resection and debulking can be challenging if an isolated posterior approach is used in all cases. In addition, the rates of post-operative complications, including infection, wound complications and pain, are high with a posterior approach and the post-operative care is demanding [2]. Furthermore, if recurrence or tumor growth occurs, repeat posterior surgery is complex with a high complication profile.

Alternative approaches include video-assisted surgery and thoracotomy. Video-assisted surgery is an attractive alternative, but accesses the spine from lateral portals and therefore does not allow direct anterior decompression.

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Furthermore, it requires endoscopic skills and lung deflation. The scapula, brachial plexus and major vessels limit access to this region by thoracotomy [3, 4]. Therefore, many specialized centers prefer an anterior approach. This typically involves a standard antero-lateral cervical approach with caudal extension by partial or complete sternotomy [2, 5–15]. Typically, for lesions cephalad of T5, the exposure requires caudal retraction of the great vessels. However, this carries the risk of vascular occlusion. If extensive anterior dissection is performed, the extent of vascular retraction can be easily visualized; however, with more limited exposures, the degree of retraction can be obscured.

This study presents, to our knowledge, the first cases of intra-operative ischaemic brain injury during anterior upper thoracic tumor resection, utilizing a partial manubrial resection. We describe the intra-operative clinical features and the current techniques employed to prevent this complication. Furthermore, we perform a cadaveric analysis of the carotid artery during this procedure to determine the likely location of vascular compromise and to determine the effect of neck positioning and aortic arch retraction on the carotid. Lastly, we analyze the rate of this complication within our institution prior to and after implementation of preventative measures.

Materials and methods

We hypothesized that intra-operative cerebral ischaemia could occur from aortic arch retraction and therefore simple measures may prevent this complication.

Firstly, we performed a comprehensive review of two cases of cerebral ischaemia occurring after upper anterior thoracic spinal surgery performed by the senior author (VP).

Secondly, we undertook a dissection of three fresh cadavers (2 males, 1 female, age range 87–101) to illustrate the effect of neck positioning on the carotid artery during this procedure. The anterior neck skin and platysma of these cadavers were resected and the left carotid artery identified. Then, an anterior approach with partial manubrial resection was performed as described by Pointillart et al. [2]. This involved a standard antero-lateral cervical approach with extension caudally by release of the sternal head of sternocleidomastoid and infrahyoid muscles 2 cm from their sternal insertion. Subsequently the manubrium was exposed between the sterno-clavicular joints. The inter-clavicular ligament was transected and a partial manubrial resection was then performed as far caudal as the junction between the sternal body and the manubrium. The retrosternal fat and large vessels were then retracted caudally and anteriorly with a long thin retractor blade (typically an Endoring retractor) fixed to the anterior thoracic vertebra with a k-wire. In our study, the inferior retractor was placed onto the T4 vertebra and maximally retracted, so that the blade of the retractor lay within the manubrial resection. Neck flexion and extension was then performed to assess the appearance of the carotid artery. In one cadaver, the relative distance between the root of the carotid artery and its entrance into the carotid canal of the skull was measured with neck flexion and extension after the inferior retractor was placed.

The rate of this complication was then analyzed in 50 consecutive cases performed prior to and 15 consecutive cases performed after the implementation of preventative measures, namely neck flexion, carotid palpation, non-invasive bi-hemispheric cerebral saturation monitoring, hemodynamic instability awareness and modification of the degree of aortic arch retraction.

Results

Case 1

A 40-year-old female with a past medical history of hypertension, type 1 diabetes and hypothyroidism presented with metastatic breast carcinoma, including extensive spinal disease particularly involving her upper thoracic spine. She had previously undergone a mastectomy and reconstruction as well as hormone therapy, radiotherapy and chemotherapy. An MRI scan of her cervico-thoracic spine revealed T2 collapse with a circumferential epidural lesion of C7-T2 with severe local spinal canal stenosis (Fig. 1).

A C7-T2 corpectomy and cement reconstruction with C6-T4 stabilization was, therefore, performed through a left-sided anterior approach utilizing a partial manubrial resection (Fig. 2).

During the procedure, which took 150 min, she was positioned with her neck in a neutral position and caudal exposure was maintained with an Endoring retractor blade pinned into T4. Her surgical and anesthetic care was otherwise unremarkable apart from moderate hemodynamic instability with unexplained fluctuations in her blood pressure occurring after placement of the retractor (blood pressure changed from a stable 90–100/60–70 mmHg to fluctuations ranging from 70–160/40–100 mmHg). Her glucose level was normal throughout the procedure, ECG was normal and hemoglobin maintained above 11 g/100 ml.

On waking she was aphasic, unable to follow simple commands, had absent right-sided reflexes and obvious right-sided hemiplegia including her face. Her left side was unaffected and moved spontaneously. She required ventilatory assistance and intermittent aspiration with naso-gastric feeding for her spontaneous, but weakened, swallowing.

Her symptoms failed to resolve and therefore urgent cross-sectional imaging was performed. These were unremarkable including her carotid arteries on an angiogram.

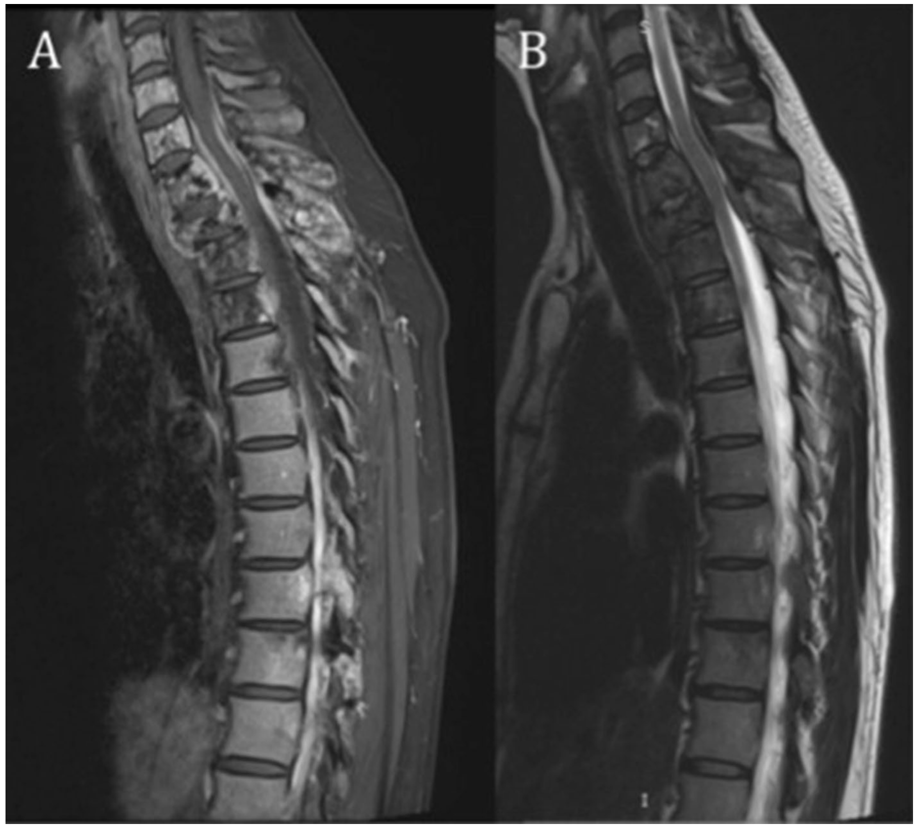

Fig. 1 Pre-operative sagittal T1 (**a**) and T2 (**b**) MRI sequences

Fig. 2 Post-operative sagittal CT scan

However, a delayed MRI scan of her brain showed ischaemic change in her left hemisphere within the left carotid artery territory (Fig. 3). Repeat carotid artery imaging again revealed no abnormality. Her blood markers, ECG and echocardiogram were all negative for a cardiovascular event or thrombotic embolization seeding from her heart.

She was, therefore, treated conservatively, but failed to recover from her cerebral ischaemia. She died 5 months later from extensive metastases.

Case 2

A 26-year-old male presented with cervico-thoracic junctional pain related to an osteosarcoma of T2 with pathological fracture and local kyphosis. He underwent T2 posterior decompression in another center and was subsequently referred to our institution to complete an anterior T1 and 2 corpectomy, tricortical iliac crest bone graft reconstruction and C7-T3 anterior stabilization (Fig. 4).

The surgical and anaesthetic care was unremarkable apart from fluctuating hemodynamic instability, which occurred soon after the insertion of the inferior retractor.

Post-operatively, he was affected by right-sided hemiplegia, dysphasia and difficulty with comprehension and understanding. These symptoms have partially recovered and he has returned to part-time work, has had two children and is still alive 10 years after surgery, tumor free. Similar to the first case, an MRI scan of his brain revealed ischaemia within the left carotid artery territory, yet cardiac ischaemic

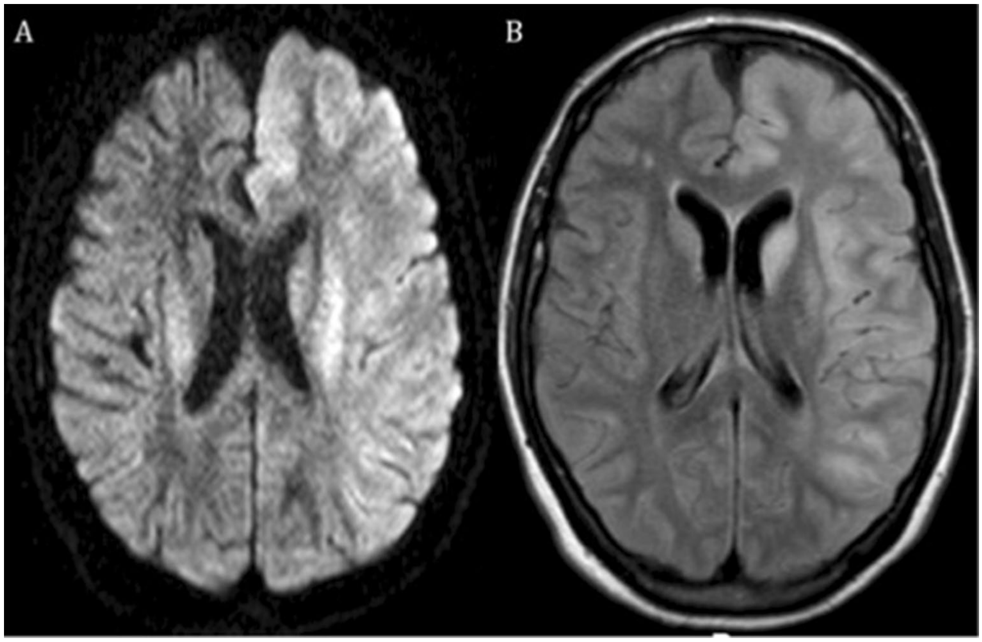

Fig. 3 Axial brain MRI scan showing left carotid artery territory ischaemic change on the T1 (**a**) and flair (**b**) sequences

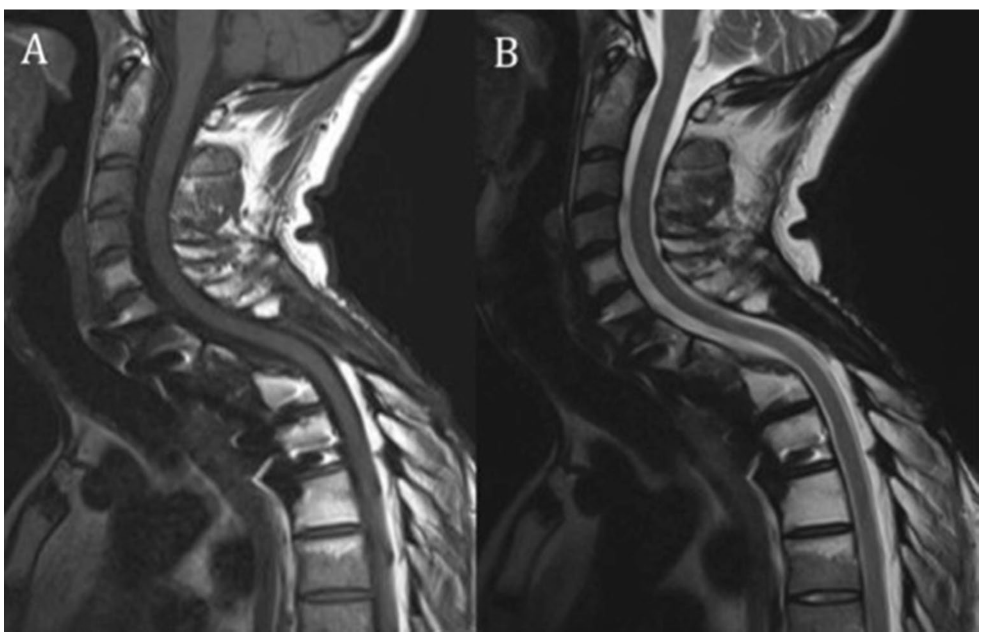

Fig. 4 Post-operative sagittal T1 (**a**) and T2 (**b**) MRI sequences

markers and cardiovascular imaging, including the carotids, were normal.

Cadaveric dissection

Figure 5 shows the effect of neck flexion and extension on the carotid artery. Note how neck extension (b) results in the initially tortuous artery (a) becoming straightened and stretched.

The relative length of the carotid artery from its root to the carotid canal increased by 2.0 cm from maximal neck flexion to maximal neck extension. This represented a 12% change in relative carotid artery length.

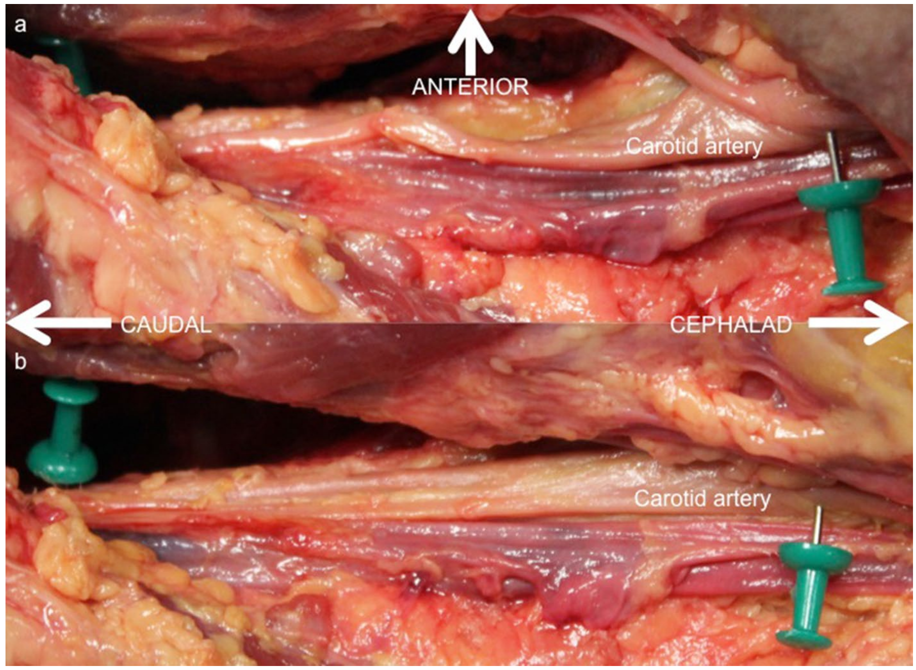

Fig. 5 The effect of neck positioning on the carotid artery. In neck flexion **a** the vessel is tortuous and lax, while in neck extension **b** the vessel is stretched and tight

The carotid root was stretched around the blade of the inferior retractor and worsened with increased caudal retraction, particularly with neck extension (Fig. 6).

In the 50 cases performed prior to the implementation of preventative measures, two cases of permanent injury from carotid artery territory cerebral ischaemia (described below) were identified.

Since the implementation of preventative measures, we have encountered two cases in which intra-operative hemodynamic instability with reduced cerebral saturations were noted, which both resolved with reduction of aortic arch retraction. No cases with evidence of post-operative cerebral ischaemia have been identified since the implementation of preventative measures.

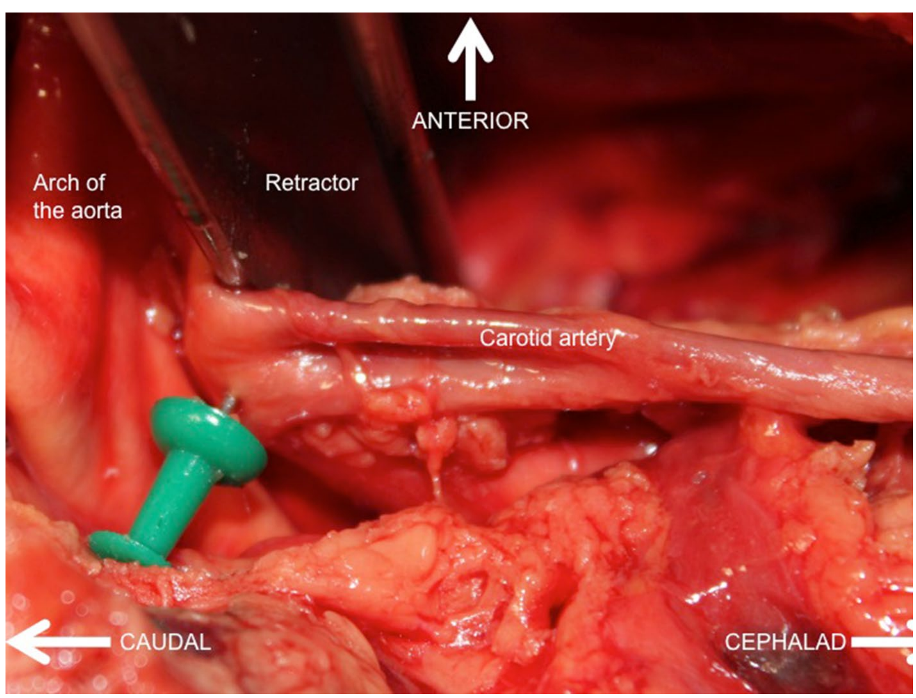

Fig. 6 Representative photograph of the carotid root (marker). Note how the carotid is stretched around the retractor representing a potential site of local occlusion

Discussion

The surgical approach used in both cases was an anterior cervical approach with partial manubrial resection without resection of the sterno-clavicular joints, which is well described by Pointillart et al. [2]. This is a challenging approach, which is complicated by significant blood loss (average 760 ml, range 100–2500 ml), dysphonia (5%), deep infection (3%), spinal cord injury (3%), thoracic duct injury (3%), haematoma requiring evacuation (3%) and pseudarthrosis (3%) [2]. However, this approach does not affect the sternoclavicular joints, it eliminates the concerns of sternal pseudarthrosis, allows direct access to the tumor and central spinal cord decompression, it provides anterior support, limits post-operative wound dehiscence, even with subsequent radiotherapy, and enhances post-operative recovery [2]. Furthermore, in the case of recurrence, this approach can be re-used and an anti-fibrosis membrane can be used at the time of the procedure to facilitate a subsequent operation.

Intra-operatively, the aortic arch and great vessels are retracted in an antero-inferior direction and held there by a retractor blade. This risks vascular occlusion, which we believe to be the cause of the cerebral ischaemia seen in our patients. However, rather than direct occlusion of the aorta from the retractor on the aortic arch, we believe that the traction causes carotid stenosis at the root of the carotid artery, which is reversible, simply by removing or limiting the retraction.

Clearly, continued occlusion during the procedure (average duration 114 min, range 60–240 min) results in permanent cerebral injury even when the retraction is removed [2]. This is what we believe happened to our two patients as evidenced by the cerebral ischaemia within the clearly defined carotid artery distribution without post-operative radiological evidence of carotid artery occlusion or injury.

The left carotid is at greater risk due to the left-sided approach used in our patients and the left carotid root originating closer to the midline than the Brachiocephalic trunk. Therefore, the left carotid root is more likely to be compressed and tractioned when the retractor is applied. Unfortunately, this predisposition and resultant left-sided hemispheric stroke risks more severe neurological consequences such as dysphasia and dominant side hemiplegia.

The authors have modified their surgical approach to limit the risk of this complication and in doing so, have not experienced any further ischaemic complications.

Firstly, patients are now positioned with the neck flexed, as this reduces the traction on the carotid artery during the retraction of the aortic arch (Fig. 5). This simple modification has not affected the surgical access, as the cephalad extent of the stabilization typically extends to the mid or lower cervical spine, rather than the upper cervical spine. However, in the rare event of a more cephalad stabilization, we would advocate removal of the aortic arch retraction while performing this part of the procedure.

Secondly, all patients now have continuous non-invasive bi-hemispheric cerebral oxygen saturation monitoring during the case. The anesthetist monitors this and if oxygen saturations drop, the retraction of the great vessels is removed.

Thirdly, the anesthetist actively monitors for hemodynamic instability after retractor placement, as this well-documented clinical finding occurs with ensuing cerebral ischaemia. If hemodynamic instability occurs, retraction of the great vessels is relieved.

Lastly, after retractor placement the carotid pulse is regularly palpated to ensure continued carotid blood flow. An intra-operative carotid doppler scan may also be used. Again, if concerns regarding carotid blood flow develop, the retraction is reduced.

Alternative anterior surgical approaches are well described and may appear favorable in the face of this severe complication. Open surgical alternatives to partial manubrial resection include partial sternotomies with or without clavicular osteotomies or complete sternotomy [5–8, 11, 15]. These approaches can provide extensive access to the upper thoracic spine and exposure of the great vessels, but carry significant morbidity related to the extensive dissections [16, 17]. Furthermore, these approaches still rely on retraction of the aortic arch to gain access to the upper thoracic spine. We therefore feel, that a more extensive anterior dissection offers no additional protection from this complication, apart from visualization of the carotid root. We reduce the traction on the aortic arch, or reposition the retractors, rather than convert to a more extensive anterior approach, if cerebral perfusion is threatened.

However, if a surgeon favors an alternative anterior surgical approach, we would continue to advocate incorporating neck flexion, cerebral saturation monitoring, hemodynamic instability awareness and carotid artery palpation in an effort to reduce the risk of cerebral ischaemia induced by retraction of the aortic arch. Furthermore, patients should be consented for these rare, but potentially devastating complications.

Conclusion

Cerebral ischaemia is a potential complication of anterior upper thoracic spinal surgery requiring retraction of the aortic arch. This most likely occurs from carotid stenosis, particularly at the carotid root, due to aortic retraction and therefore, may be reduced by positioning the patient with neck flexion. Continuous non-invasive monitoring of cerebral saturation, as well as actively monitoring for hemodynamic instability and reduced carotid pulsation after retractor placement, allows for early detection of this complication.

If detected, perfusion can be easily restored by reducing the retraction of aortic arch.

Acknowledgements Glynny Kieser for her editorial input.

Compliance with ethical standards

Conflict of interest None of the authors have any potential conflict of interest.

Funding Nil.

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