Thromboendarterectomy and circulatory arrest[†]

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Abstract

Thromboendarterectomy remains a high-risk procedure. The use of circulatory arrest as a technique to allow pulmonary artery visualization is associated with cerebral and organ damage secondary to the ischaemic insult. Application of techniques learned from thoracic aortic stenting and minimal invasive valvular surgery may mean that circulatory arrest becomes an uncommon accompaniment to thromboendarterectomy.

Keywords: Pulmonary thromboendarterectomy • Circulatory arrest • Endo-aortic balloon

INTRODUCTION

Thromboendarterectomy for the removal of chronic thromboembolic material is usually performed under circulatory arrest due to the problem of blood swamping the operative field [1, 2]. This blood only has two sources if full bypass has been initiated with caval snaring, the bronchial circulation and systemic collaterals.

Circulatory arrest is associated with cerebral and organ dysfunction secondary to the ischaemia during the circulatory arrest [3]. Selective cerebral perfusion has been utilized to reduce the cerebral complication rate, although the deleterious effects of the organs of the lower body remain [4].

HYPOTHESIS

Selective control of the bronchial arteries at the time of surgery may potentially reduce the back bleeding during the thromboendarterectomy and negate the need for a circulatory arrest. Unfortunately, anatomy precludes a surgical mechanism of control, hence the use of circulatory arrest. The improvement in balloon and stent technology may help the surgeon adopt a hybrid approach.

BRONCHIAL ARTERY ANATOMY

The bronchial arteries have highly variable origins, branching patterns and courses; however, they usually arise between the T5 and T6 vertebral levels [5]. Four different branching patterns have been described [6] (Fig. 1).

Bronchial arteries that originate outside the area between the T5 and T6 vertebrae at the level of the major bronchi are

considered to be anomalous, and occur in up to 35% of patients [6, 7]. They arise from the aortic arch (the majority), internal mammary artery, thyrocervical trunk, subclavian artery, costocervical trunk, brachiocephalic artery, pericardiophrenic artery, inferior phrenic artery or abdominal aorta.

Aberrant bronchial arteries are distinguished from non-bronchial systemic collateral vessels in that they extend along the course of the major bronchi. Non-bronchial systemic collateral vessels enter the pulmonary parenchyma through the adherent pleura or via the pulmonary ligament, and their course is not parallel to that of the bronchi [7]. The significance of systemic collaterals in causing blood in the thromboendarterectomy operative field is unknown.

PROPOSED HYBRID ALTERNATIVE TO CIRCULATORY ARREST

- (1) Pre-procedural MRI angiography would help delineate the bronchial artery anatomy.
- (2) Cannulation options could include ascending aorta and either the descending aorta through the posterior pericardium or the femoral artery, so that lower body perfusion occurs during the balloon inflation/stent deployment.
- (3) Spinal drainage of the CSF in an attempt to reduce the incidence of paraplegia.
- (4) Using a hybrid theatre, an intra-aortic balloon occlusion device or a removable stent could be deployed to temporarily occlude the bronchial arteries. The stent/balloon would only be inflated/deployed just prior to the pulmonary artery has been opened. Motor and sensory evoked potentials could be utilized to assess the safety of this manoeuvre, and if issues arise then the balloon is deflated or stent removed and a standard operative approach utilizing circulatory arrest could be undertaken.

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Figure 1: Bronchial artery anatomy. The approximate percentage incidence of the variations is shown. RBA: right bronchial artery; LBA: left bronchial artery.

(5) The whole procedure could be performed at moderate hypothermia.

A possible proposed set up is shown in Fig. 2.

SUMMARY

The development of modern endo-aortic balloon technology and removable aortic stents [8] may help reduce the need for circulatory arrest in patients undergoing thromboendarterectomy. An experimental animal feasibility study potentially followed by a clinical pilot study is needed to assess the proposed technique, and to assess the benefits/drawbacks of intra-aortic balloon or stent deployment.

Paraplegia remains a dreaded fear of any thoracic aortic occlusive device. Pre-operative MRI will help determine the extent of thoracic aortic coverage and number of large bronchial arteries involved; however, as in the field of aortic surgery, this technique has limitations [9]. Patients with numerous large bronchial arteries, or with a long area of origin in the thoracic aorta, and

Figure 2: Possible set up to avoid circulatory arrest by occluding bronchial artery supply to the lungs. Gray oval represents endo-aortic balloon catheter.

those that involve distal arch/proximal descending aorta may not be suitable. Single zone stenting is thought to carry a very low risk of paraplegia [10].

Motor evoked and sensory evoked potentials play an important part in the management of the spinal cord in thoracoabdominal aneurysm surgery [11]. Their utilization with the proposed technique may help reduce the incidence of paraplegia, which is very low in circulatory arrest cases not involving the descending aorta, such as thromboendarterectomy procedures. The utilization of CSF drainage will also need to be evaluated.

Aortic dissection, systemic embolization and vascular injury are all risks associated with endo-aortic manipulations. Aortic kinking, arch curvature, aortic aneurysm and atherosclerotic load will also all affect the risk of an endo-aortic manipulation, and these will need to be balanced against the risk of a circulatory arrest.

Non-bronchial systemic collateral vessels contribute a highly variable extent to pulmonary blood flow, and their presence can be difficult to detect pre-operatively, but CT angiography is a potentially useful investigative tool [12].

Selective pre-operative embolization may control the back bleeding, but has significant side effects, which include paraplegia [13]. Bronchial arteries tend to originate from the T5 to T6 region of the thoracic aorta implying that a relatively short occlusion device could be utilized, reducing the chance of spinal cord ischaemia, as inadequate coverage would negate the use of this technique.

This technique may potentially be applicable to anyone undergoing thromboendarterectomy who does not have a contraindication to temporary bronchial artery occlusion. The advantages of this technique may be greatest in those that have the highest risk from circulatory arrest, such as elderly patients, or those that will require prolonged procedures.

Quantification of the risks from circulatory arrest is difficult as the technique is usually part of the surgical technique; however, in the field of aortic surgery, the avoidance of circulatory arrest is thought to be of benefit to patients, although no level 1 evidence exists.

Cost implications are important in today's medical practice, but often difficult to quantify. The cost of an interventional procedure prior to the surgery in a hybrid suite may seem high, but the cost of intensive care is many times higher, potentially reducing costs secondary to the reduction in the morbidity from circulatory arrest. The avoidance of circulatory arrest will also reduce the cardiopulmonary bypass times and blood and clotting factor utilization, both of which are associated with increased morbidity.

We present this work as a new idea for discussion.

Conflict of interest: none declared.

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eComment. Thromboendarterectomy and aortic occlusion: the good, the bad and the ugly

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The article by Poullis [1] brings home an important problem of operative field flooding while performing thromboendarterectomy. The novel idea from Poullis [1] of intra-aortic balloon deployment at the level of the origin of the bronchial

arteries seems like an attractive simple option that may significantly reduce bronchial artery blood flow and flooding of the pulmonary vascular system while maintaining organ perfusion and avoiding circulatory arrest.

Although Poullis briefly mentioned the risks of aortic and vascular injury and embolization during intra-aortic balloon deployment, we would like to emphasize that these are real risks that are not to be neglected. From a recent large series of endovascular stenting for descending thoracic aortic pathology, 5.7% had complication from vascular access injury requiring emergency rescue iliac-femoral artery bypass and 1.9% had cerebral embolic event [2]. Elderly patients, those with atherosclerotic and calcified aortas, and peripheral vascular disease are particularly at risk. Therefore, careful patient selection may be the key to minimizing morbidity from this intra-aortic balloon approach.

In terms of spinal cord ischemia during intra-aortic balloon deployment, apart from the utilization of motor and sensory evoked potential monitoring and CSF drainage to minimize cord ischemic injury, the administration of perioperative steroids such as methylprednisolone, can also be considered to help reduce spinal cord inflammation and ischemic injury, in order to reduce incidence of paraplegia [3]. In order to prevent spinal cord ischemia, an alternative bronchial artery occlusion strategy would be to place highly selective small balloon occluders within the bronchial arteries, totally avoiding any thoracic aortic flow occlusion, further limiting the risks to the spinal cord. Furthermore, latest innovations in intra-vascular occlusion polymers such as LeGoo?, which is a reverse thermo-sensitive polymer that provides temporary internal vessel occlusion may be injected inside the bronchial arteries via a catheter obviating the need for any balloon deployment [4].

Bronchial artery occlusion by intra-aortic balloon under moderate hypothermia may have additional consequences in terms of lung ischemia reperfusion injury [5]. The lung is dependent on the pulmonary artery, bronchial artery, and alveolar ventilation to oxygenate lung tissue to prevent ischemia. Variable systemic collaterals to the lungs may have a minor role in contributing to lung perfusion. The status during circulatory arrest for thromboendarterectomy is that of no pulmonary artery, no bronchial artery and no systemic collateral lung perfusion but with lung protection from hypothermia, whereas Poullis's approach will result in some systemic collateral lung perfusion under the lesser protection of moderate hypothermia. The effects of these techniques on lung ischemia reperfusion injury will need further evaluation [5]. Furthermore, perhaps worth studying would be the potential protective role of pulmonary ischemic preconditioning with a short duration of intra-aortic balloon inflation prior to the prolonged deployment to reduce the effects of lung ischemia-reperfusion injury [5].

We applaud the novel idea by Poullis of intra-aortic balloon bronchial artery occlusion during pulmonary endarterectomy to reduce operative field flooding while avoiding circulatory arrest, nevertheless, the good, the bad and the ugly of these strategies will require further investigations.

Conflict of Interest: None declared

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