Case Report

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Hybrid Open and Endovascular Management of a Gunshot Wound to the Carotid Artery

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In addition to standard open surgical techniques, major hemorrhage is increasingly being managed using hybrid (open and endovascular) surgery. We present a case of hybrid management of a carotid artery injury secondary to an oropharyngeal gunshot wound. After performing balloon catheter tamponade with an inflated intraoral Foley catheter, on-table transfemoral angiography demonstrated extravasation from the external carotid artery with arteriovenous fistulization to the internal jugular vein. An endovascular stent graft was deployed, spanning from the common carotid to the internal carotid artery. This facilitated surgical neck exploration and ligation of the external carotid artery and jugular vein injury in zone II/III of the neck while maintaining antegrade cerebral blood flow. The approach presented represents a feasible and effective means to manage these types of difficult-to-access injuries in the endovascular and hybrid surgical era.

Keywords: *Penetrating Trauma; Head and Neck; Wounds and Injuries; Noncompressible Hemorrhage; Angiography*

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INTRODUCTION

In addition to standard open surgical techniques, major hemorrhage is increasingly being managed using hybrid (open and endovascular) surgery [1–5]. Vascular surgeons were first to develop hybrid open-endovascular techniques for managing abdominal aortic aneurysms and peripheral artery occlusive disease [6–9]. However, along with increasing use of endovascular therapies for hemorrhage control (including embolization techniques, covered stent grafts, and resuscitative endovascular balloon occlusion of the aorta (REBOA)) has come a growing interest in the use of hybrid techniques in trauma [2,3,5,10–20].

Traditionally, upon leaving the trauma bay, surgeons needed to decide whether the patient should be transported to the computed tomography (CT) scanner, operating room, or interventional radiology suite. To avoid having to decide whether to take the patient to one of these three distinct, geographically separate environments, there has been an emergence of hybrid operating suites, in which surgeons may perform both open surgical and endovascular therapies depending on acuity, complexity, and evolution of the clinical scenario [21–24]. In these settings, traditional surgical and endovascular care can be delivered not only simultaneously (e.g., laparotomy for solid organ hemorrhage combined with embolization of a bleeding pelvic vessel), but also in sequence [23]. For example, temporary or partial control of bleeding can be obtained with endovascular stenting, making definitive hemorrhage control with open operative techniques more facile and limiting further blood loss in areas difficult to manage with operative exposure alone.

We present a case of hybrid open and endovascular management of an external carotid artery gunshot wound (GSW). The case demonstrates the utility of endovascular bleeding control in combination with traditional open operative exposure and provides a framework for future hybrid management of penetrating vascular injuries.

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Ethical Approval and Informed Consent

Ethical approval was not required. Informed consent for reporting of this case was obtained from the described patient verbally and via e-mail.

CASE

A 19-year-old male was brought to the Emergency Department of our regional trauma centre by paramedics after he sustained a GSW to the mouth and left neck. He was alert, oriented, moving all extremities, and vitally stable aside from being tachycardic (blood pressure 107/75, heart rate 118 bpm). There was significant hemorrhage coming from the oral cavity and a large expanding left neck hematoma. Initial resuscitation included an Emergency Department cricothyrotomy to secure the airway, oral packing with gauze sponges, placement of a right-sided femoral large-bore central venous access line (Cordis; Cardinal Health Inc., Santa Clara, California, USA), transfusion of packed red blood cells and fresh frozen plasma, and infusion of 1g of tranexamic acid. X-rays of the chest and neck were obtained and the patient was then transferred directly to the operating room (Figure 1).

In the operating room, the oral cavity was inspected revealing a penetrating injury to the proximal tongue and left posterior oropharynx. For immediate, temporary hemorrhage control, balloon catheter tamponade was performed by inserting a Foley catheter with a 20 cc balloon into the missile tract and inflating and repositioning it until external hemorrhage ceased. The patient was then prepped and draped in the supine position on a fluoroscopy-compatible table, such that the neck, torso, and groins were exposed. As the hemorrhage was completely controlled with balloon catheter tamponade, and a high, zone II/III carotid artery injury was suspected, we elected to proceed with a transfemoral angiogram prior to neck exploration.

We inserted a 6-French 90-cm long sheath into the left common femoral artery and used this to access the aortic arch and carotid arteries. A pigtail catheter was positioned in the aortic arch and used to perform angiograms of the left common, internal, and external carotid arteries (CCA, ICA, ECA, respectively). Initial imaging was difficult to interpret given the extravasation, drop-out artifact created by missile fragments, and presence of a high-flow arteriovenous fistula to the jugular vein. Selective angiography in the anterioposterior and lateral views with a portable C-arm demonstrated an intact left ICA and CCA. It also revealed contrast extravasation from the left ECA in distal zone II, approximately 3-cm distal to the carotid bifurcation, and an arteriovenous fistula between the ECA and internal jugular vein with retrograde filling of the cerebral sinuses (Figure 2).

After consideration of various options, we elected to proceed with hybrid open and endovascular surgical

Figure 1 Location of missile fragments at junction of zone II and zone III of the neck.

Figure 2 Left external carotid artery (ECA) injury with extravasation of contrast, as well as an arteriovenous fistula between ECA and internal jugular vein.

management. Following systemic heparinization, a 0.035 inch Rosen wire (Cook Medical LLC, Bloomington, Indiana, USA) was positioned in the distal ICA. Distal embolic protection was not used as the carotid bulb appeared patent and free of disease or clot. We weighed the risk of hemorrhage or prolonged cerebral ischemia with proximal CCA clamping during open surgical repair against that of poor stent patency in a young person and decided to proceed with endovascular stenting. A 7 mm x 5 cm Gore Viabahn self-expandable endoprosthesis (W. L. Gore and Associates Inc., Flagstaff, Arizona, USA) was deployed spanning from the distal left CCA to the proximal ICA. We subsequently post-dilated the endoprosthesis with a 7 mm × 40 mm Mustang balloon dilatation catheter (Boston Scientific Corporation, Marlborough, Massachusetts, USA). Angiography demonstrated stent patency with minimal antegrade flow into the ECA and arteriovenous fistula (Figure 3).

The left neck was then explored via a longitudinal incision along the anterior border of the sternocleidomastoid muscle with extension posterior and inferior to the left earlobe. The subcutaneous tissues were extensively infiltrated with blood and clot. With the vagus nerve protected, dissection of the proximal aspect of the CCA was undertaken in the retrojugular plane. As the dissection approached the carotid bifurcation, we encountered arterial and venous bleeding from the more distal portion of the incision underneath the mandible (distal zone II or proximal zone III). The bleeding was controlled with manual digital pressure until the dissection of the ICA and ECA was completed. The ECA was found to be completely transected with a large defect in the path of a missile fragment. The proximal end of the transected ECA was not bleeding and was subsequently surgically ligated just distal to the carotid bifurcation. The distal, actively bleeding branches of the ECA were surgically ligated. The high venous bleeding, presumably from a partially transected internal jugular vein, was not easily accessible for surgical exploration but was easily controlled by packing with Surgicel (Ethicon Inc., Cincinnati, Ohio, USA).

At this point, all bleeding had been controlled. Repeat completion angiography demonstrated stent patency with satisfactory opacification of the distal intracranial vasculature based on anterioposterior and lateral views (Figure 4). The ECA was successfully ligated with no further extravasation or arteriovenous fistula from antegrade or retrograde blood flow. The aero-digestive structures of the neck did not appear to be injured. A Jackson-Pratt closed suction drain was left in the operative field and tension-free closure of the wound was obtained by raising a small local advancement flap. Final exploration and repair of injuries to the oral cavity were then completed by an ear, nose, and throat (ENT) surgeon.

Post-operatively, the patient remained in hospital for 30 days. He was started on dual antiplatelet therapy,

Figure 3 Patent stent deployed across external carotid artery (ECA) origin with minimal antegrade flow into the ECA and arteriovenous fistula.

which will be continued indefinitely. He underwent conversion of his cricothyrotomy to a formal tracheostomy, placement of a percutaneous endoscopic gastrostomy tube for feeding, and an external fixation device for management of associated mandibular fractures. Since discharge from hospital, follow-up CT imaging has revealed patency of the stent. Further, the gastrostomy tube and tracheostomy have been removed, and he is awaiting surgery for mandible reconstruction. Follow-up Duplex ultrasonography has revealed patency of the self-expandable carotid stent without stenosis or flow irregularities.

DISCUSSION

We have presented a case of hybrid management of a GSW to the oropharynx and neck. In this case, we elected to forego CT imaging given the hard signs of vascular injury. Appreciating the potential challenge of neck exploration for a high zone II/III injury, on-table angiography was performed after temporary hemostasis was achieved with balloon catheter tamponade with an intraoral Foley catheter. The angiogram demonstrated an ECA injury complicated by fistulization to the internal jugular vein. Various options were considered, including immediate neck exploration, neck exploration following CCA-ICA balloon occlusion, and neck exploration following CCA-ICA covered stenting to exclude the ECA. After intraoperative multidisciplinary consultation

Figure 4 Patent stent with satisfactory opacification of the intracranial vasculature.

between vascular surgery, trauma surgery, interventional neuroradiology, neurosurgery, and ENT, it was determined that covered stenting would afford the best chance for hemorrhage control while maintaining antegrade cerebral blood flow. However, this may be offset by the potential short- and long-term sequelae of placing a carotid stent in the setting of a contaminated wound in a young individual, which was acknowledged. As it was suspected that the injury was high and potentially in zone III, availability of a hybrid operating environment capable of percutaneous and open vascular surgery was essential.

Hybrid surgical approaches in trauma are now well-described, and REBOA is a prime example of the utility of endovascular approaches as a bridge to definitive hemorrhage control [2–5,10–13]. Beyond the use of balloon occlusion of the aorta for pelvic injuries, much of the literature has focused on the use of balloon occlusion, embolization, or stenting in anatomic regions that are difficult-to-access with traditional open surgical techniques, such as the proximal groins and subclavian and innominate arteries [25–34]. Patients with zone III carotid artery injuries can present a specific challenge, in that obtaining proximal and distal control of the vessel may prove technically difficult and/or consequential with prolonged ischemic times. In such cases, angiography is a useful tool to identify the site of injury and may facilitate use of endovascular techniques better suited to gaining control of bleeding in this anatomic region, particularly in zones I and III of the neck [35–37]. Indeed, while REBOA is a useful bridge to definitive open surgical management, initial on-table endovascular techniques are useful not only for temporary balloon occlusion, but also for diagnosis of complex vascular injuries and may lead to potentially less morbid endovascular therapies such as the use of covered stents.

The use of covered stents to exclude an area of injury in the carotid arteries has been described elsewhere in the literature [38–40]. Duane et al. (2002) reported the case of a 31-year-old woman who developed a left ICA pseudoaneurysm following a stab wound, and of a 27-year-old woman who was shot in the right neck and was found to have a right ICA-to-internal jugular vein arteriovenous fistula [38]. In the first case, a CCA cutdown was performed and a 12-mm wall graft was placed. On follow-up angiogram, the graft had unfortunately become completely occluded. This is not necessarily a common complication, with one study of over 100 patients demonstrating 79.6% stent patency at 2 years [41]. The second patient underwent endovascular placement of a covered stent across the fistula with maintenance of cerebral blood flow and a favourable outcome. McNeil et al. (2002) similarly reported deploying a stent across an ICA pseudoaneurysm with a good neurologic outcome [39]. In the non-trauma literature, Marine and Sarac (2012) described deployment of a covered stent for an iatrogenic right CCA pseudoaneurysm and arteriovenous fistula [40].

Despite the success described in previous reports of endovascular stenting of carotid injuries, some have advocated for a primarily open surgical approach to penetrating carotid artery injuries, particularly in zone II [36]. Although there is a lack of morbidity associated with exposure in zone II of the neck and reasonable short- and medium-term outcomes have been reported with an exclusively open approach, the injury in our patient was felt to be high and potentially in zone III [36]. These factors, as well as the long-term sequelae of stenting were considered, especially given the young age of our patient. The need for lifelong antithrombotic therapy was acknowledged given that our patient was young. With respect to complications, infection was considered given that the stent was being placed in a contaminated field. While the consequences of graft infection could be devastating, carotid artery stent infections are rather rare in the literature, and this risk was weighed against the potential neurological effects of reduced cerebral blood flow and the risk of hemorrhage [42]. Occlusion or stenosis as well as leak have been reported in 10.6% and 5.3% of patients undergoing carotid artery stenting, respectively [41]. However, given the nature of the injury and the aforementioned risks of hemorrhage as well as the importance of maintaining cerebral perfusion, the benefits of stenting were felt to outweigh the risks.

Interestingly, the case we have presented represents a not-yet-explored intersection of the aforementioned

literature. First, while both open surgical and endovascular management of penetrating injuries have been reported, this is, to our knowledge, the first description of a hybrid open-endovascular approach to a penetrating ECA injury. Second, the means by which the covered stent was used to provide hemorrhage control has also not been previously described in this specific context to our knowledge . In the extant literature pertaining to endovascular management of penetrating carotid artery injuries, covered stents have been deployed across pseudoaneurysms and arteriovenous fistulas, or combinations thereof [38–40]. However, we are the first, to our knowledge, to report use of a covered stent to occlude the origin of the ECA prior to its ligation (i.e., to provide proximal control), minimizing blood loss during surgical exploration and maintaining cerebral blood flow in the setting of an unknown degree of collateralization.

Overall, while both open surgical and endovascular techniques can be successful in managing penetrating neck injuries, their simultaneous or staged use in a hybrid fashion represents an innovative approach with rapid proximal control of bleeding followed by definitive surgical hemorrhage control. In appropriate cases, endovascular techniques can be used as an adjunct to open surgery, reducing blood loss and the chances that open exploration devolves into significant, difficult-to-control bleeding and worsening instability, while maintaining antegrade perfusion to vital organs. Hybrid surgical techniques may also foster multidisciplinary, collaborative operative environments, creating space for different skill sets and potentially leading to the formation of novel surgical techniques.

The approach described above has some limitations. First, the patient's external bleeding could be controlled with a Foley catheter in the missile tract, allowing time to complete angiography and plan the hybrid approach. In patients with multiple areas of external bleeding or multiple significant injuries leading to instability, there would likely not be time to characterize the neck injuries with angiography prior to emergent surgical exploration. Second, placement of a synthetic graft in a potentially contaminated field is not extensively studied, and the role for long-term antithrombotic prophylaxis remains undefined. Nonetheless, where patient factors and injury patterns allow, the combination of angiography to characterize injuries, endovascular attainment of proximal bleeding control, and definitive repair with open surgery represents an attractive option for management of penetrating carotid artery injuries.

CONCLUSION

We present the case of a GSW to the left neck, with demonstration of a hybrid open-endovascular approach to manage an ECA injury and arteriovenous fistula. Hybrid surgery extends beyond simple balloon occlusion and bridging to open repair and allows for the consideration of more advanced endovascular techniques as well as multidisciplinary collaboration. The combination of diagnostic angiography and endovascular stenting to gain proximal control of the injured ECA while maintaining antegrade cerebral blood flow prior to open surgical neck exploration and ECA ligation represents a feasible and effective means by which to manage penetrating carotid artery injuries in the era of increasing use of endovascular and hybrid approaches.

Ethics Statement

(1) All the authors mentioned in the manuscript have agreed to authorship, read and approved the manuscript, and given consent for submission and subsequent publication of the manuscript.
(2) The authors declare that they have read and abided by the JEVTM statement of ethical standards including rules of informed consent and ethical committee approval as stated in the article.

Conflicts of Interest

The authors have no relevant conflicts of interest to declare.

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Author Contributions

All authors had access to the relevant case information and were involved in manuscript preparation and final approval.

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