

# Selected abstracts accepted for the EVTM St Petersburg meeting 7th June 2019

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## A Bespoke Selective Aortic Arch Perfusion Catheter, Delivered with Intravascular Ultrasound Guidance, Allows Simultaneous Aortic Occlusion and Retrograde Perfusion in a Pressurised Human Cadaveric Model: A First-In-Human Feasibility Study

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**Background:** Resuscitative endovascular balloon occlusion of the aorta (REBOA) is becoming an established therapy for achieving rapid aortic control of severe haemorrhage. It is an attractive endovascular solution for the prehospital and austere military damage control setting. If passive aortic control is not enough to stabilise the patient, or if effective cardiac output is lost, the ability to retrogradely infuse into the aorta, upstream of the occluding balloon is an attractive manoeuvre. This should improve coronary and cerebral perfusion, avoiding prolonged cerebral and myocardial hypoperfusion and resulting injury. A bespoke selective aortic arch perfusion (SAAP) catheter has been effective in animal models of traumatic cardiac arrest but has not been demonstrated in a human model to date.

**Methods:** A bespoke SAAP catheter was introduced via a 14 Fr femoral arterial sheath into the aorta of a Thiel-preserved externally-pressurised cadaveric model. Fluoroscopic and intravascular ultrasound (IVUS) guidance were used to confirm balloon placement in the aorta, and that deployment had been achieved with apposition of the balloon to the vessel wall.

**Results:** The SAAP catheter delivered easily without the need for a guidewire, under direct fluoroscopy using standard techniques. Balloon apposition to the aortic wall was achieved and confirmed using a digital IVUS catheter. Retrograde infusion of a 50:50 mixture of normal saline and iodinated contrast was performed by hand-injection, and fluoroscopic imaging confirmed the ability to perfuse carotid, vertebral and coronary vascular beds. No aortic wall injury was noted on subsequent angiography.

**Conclusion:** For the first time, in a human pressurised cadaveric model, SAAP of the aorta has been made possible via a bespoke catheter. This procedure combines simultaneous aortic occlusion with the ability to retrogradely perfuse the cardiac and cerebral circulations, which are of key importance during cardiac arrest and states of low-output.

# Feasibility and Clinical Outcome of REBOA in Patients with Impending Traumatic Cardiac Arrest

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**Background:** Resuscitative endovascular balloon occlusion of the aorta (REBOA) may improve systolic blood pressure (SBP) in hypovolemic shock. It has, however, not been studied in patients with impending traumatic cardiac arrest (ITCA). We aimed to study the feasibility and clinical outcome of REBOA in patients with ITCA using data from the ABO Trauma Registry.

**Methods:** Retrospective and prospective data on the use of REBOA from 16 centers globally were collected. SBP was measured both at pre- and post-REBOA inflation. Data collected included patients' demography, vascular access technique, number of attempts, catheter size, operator, zone and duration of occlusion, and clinical outcome.

**Results:** There were 71 patients in this high-risk patient group. REBOA was performed on all patients, in a majority using a 7 Fr catheter placed on the first attempt through blind insertion and inflated in Zone I for a period of 30 to 60 minutes by emergency room doctors, trauma surgeons or vascular surgeons. SBP significantly improved following the inflation of REBOA and 38% of the patients survived.

**Conclusions:** Our study has shown that REBOA is feasible in patients with ITCA, SBP can be elevated and 38% of the patients survived.

## Hepatic Arterial Embolization in the Management of Liver Trauma: Fourteen Years of Experience in a Reference French Trauma Center

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**Background:** Retrospective observation study of hepatic arterial embolization (HAE) procedures among 485 patients with liver trauma admitted in a referral trauma center for 14 years (2004–2018).

**Methods:** From 2004 to 2018, 48 patients (10%) underwent HAE in Grenoble-Alpes Trauma Center for the treatment of a liver trauma (4 penetrating and 44 blunt). The degree of hepatic injury according to AAST grade, hemodynamic status at the time of admission, demographic data, the timing of procedures, and complications was assessed.

**Results:** There were 28 men and 20 women, with a mean age of 36.2 years. Thirty-eight patients had a liver trauma of grade 3 and over (79%). Fourteen patients were in shock at the admission. One-month mortality was 6%. The main complications were inflammatory syndrome (25%), abdominal compartment syndrome (ACS) (21%), biliary leak and biloma (17%), and liver ischemia (13%). Indication of HAE was based on CT scan contrast leakage in the initial CT in 33 cases (71%), aneurysm in 2 cases and arteriovenous fistula in 1 case. Eleven (24%) patients with unresponsive shock underwent surgery and/or SAE without a CT scan.

In all patients, bleeding was stopped (HAE success rate was 100%), with 3 patients require re-embolization (first HAE success rate 94%). Thirty-two patients required surgical intervention before or after embolization (67%): 11 hepatic packing, 4 hepatic resections, and 17 lavage laparoscopy. Four Pringle maneuvers were performed, two temporary and in two cases the tourniquet was lifted through the incision and released in the arteriography room to allow embolization.

The initial procedure was: a) Primary HAE (HAE at admission): 27 cases (56%). Seventeen patients had secondary surgery (12 laparoscopic lavages, 2 hepatic packing, 2 delayed hepatic resections, and 1 laparoscopic cholecystectomy for gallbladder necrosis). b) Combined HAE (HAE + laparotomy during the same hour at admission): 6 cases (13%). c) Secondary HAE after laparotomy (laparotomy then HAE): 5 cases (10%). d) Secondary HAE after nonoperative management (NOM) (NOM then HAE): 10 cases (21%).

Fifteen patients were embolized with coils or microcoils, 17 with resorbable gel, 6 with coils, 3 with a plug or prosthesis, 2 with Lipiodol and Histrocryl, and 5 with combined devices. The median time to embolization was 3.38 hours and 62.5% of the patients were embolized within the first 6 hours following their arrival at the Trauma Center.

**Conclusion:** Overall, 10% of admitted hepatic trauma undergoes HAE in our center, with a median time to embolization of less than 4 hours, a mortality rate of 6% and an HAE success rate of 93% in our series (100% after re-embolization), comparable to data of a recent meta-analysis showing a success rate of 80–97% and a mortality rate of 1–8%.

## Endovascular Techniques to Treat Pancreatogenic Hemorrhage

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**Background:** Pancreatogenic bleeding is concerning because even patients treated by open surgery have a high rate of fatality. According to current literature, endovascular embolization is a highly effective method of hemorrhage control in such scenarios. It has also been shown, that the transfer to a higher level of care facility improves outcome. Our hospital is an only regional facility that has all the capabilities to treat complex pancreatic pathology. The aim of this study was to create a logistic system for the treatment of patients with pancreatogenic bleeding and evaluate the effectiveness of endovascular techniques.

**Methods:** A retrospective study of patients with pancreatogenic hemorrhage who underwent embolization and were admitted to our hospital during March 2012–November 2018 was performed. At the beginning of this study period, a system of communication and feedback in all regional hospitals, criteria for transportability, pancreatic-focussed protocols to diminish delivery time and time to embolization and special CT-protocols were created. An angiosuite was started on a 24/7 basis with interventional radiologists available in-house.

**Results:** Sixty-five embolizations were performed on 61 patients during the study period. Forty-eight patients were referred from other hospitals in Ekaterinburg and from the Sverdlovsk region. Among the sources of bleeding, most of the patients ( $n = 33$ ) suffered from hemorrhagic complications of chronic pancreatitis, 19 from necrotizing pancreatitis, and 9 had postoperative hemorrhage after pancreatic surgery. Technical success was achieved in 100% of the cases. The clinical effect of embolization was noted in 93%. Four patients necessitated additional endovascular embolization procedures, of which 2 patients had a bleeder in another artery (not pancreatic). One patient developed severe colon ischemia which resulted in a colostomy.

**Conclusion:** Endovascular embolization is an effective tool for hemorrhage control in severe pancreatogenic bleeding. Developed logistics, new diagnostics, and treatment protocols are essential to reduce mortality and morbidity.

## Effectiveness of Endovascular Hemorrhage Control in Gastrointestinal Bleeding

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**Background:** The aim of this study was to evaluate the effectiveness of endovascular techniques for gastrointestinal (GI) bleeding with a high risk of recurrence.

**Methods:** A retrospective study of patients with GI bleeding treated in our facility during a period of 2 years (2017–2018) was performed. All patients underwent primary gastroduodenoscopy. The type of bleeding was classified by Forrest (F). Risk of recurrent bleeding was assessed using the Rockall's system. All patients received antisecretory therapy. If conservative treatment failed and there was a high risk of recurrent bleeding, endovascular techniques were then used to control the bleeding.

**Results:** This study enrolled 160 patients. Sources of recognized bleeding were distributed as follows: duodenum peptic ulcer – 69 (43.1%) patients, stomach ulceration – 65 (40.6%), gastric cancer – 23 (14.4%), and gastroduodenal artery pseudoaneurysm as a consequence of chronic pancreatitis – 3 (1.9%). In 98 patients (61.2%) with F1-F2b bleedings, combined endoscopic hemostasis was used. Sixty-two (63.2%) patients were successfully treated by conservative methods. Thirty-six (26.8%) underwent endovascular surgery. The left gastric artery was embolized in 10 patients with chronic gastric ulceration and 13 patients with gastric cancer (Group 1). Ten patients with chronic duodenum ulcer and 3 with pseudoaneurysms, were scheduled for gastroduodenal artery embolization (Group 2).

Technically successful embolization in Group 1 was performed in 60.8% of cases (8 with gastric ulcers and 6 with cancer). The remaining 9 patients underwent conservative treatment. Bleeding reoccurred in these patients in 77.7% of cases ( $n = 7$ ). Among them, 4 underwent repeated endoscopic hemostasis, 3 had open surgery (subtotal gastric resection or bleeding point suturing). Six patients died (66% lethality rate). Clinical effectiveness of the left gastric artery embolization was achieved in 71.4% of cases ( $n = 10$ ). Recurrence of bleeding was recorded in 4 patients (28.6%). Two patients died (14.3%). Another two patients underwent additional endoscopic hemostasis.

In Group 2, technical success was achieved in 100% of cases. However, in 15.4% ( $n = 2$ ), bleeding reoccurred. Either repeated endoscopy or open surgery was needed to control the bleeding. One patient died (7.7%).

**Conclusion:** Endovascular surgery allows the achievement of hemostasis in 71% of patients with a high risk of rebleeding and diminishes mortality and morbidity.

# Endovascular Hemorrhage Control of Postoperative Pancreatic Hemorrhage

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**Background:** Pancreatic resections are usually performed for tumors and complicated chronic pancreatitis. Although lethality is decreasing to 5%, a number of postoperative complications remain high even in specialized centers and can reach 50%. The most dangerous and severe complication in pancreatic surgery is postoperative bleeding. It accounts for 4–30% and is associated with lethality of about 3–60%. The aim of our study was to analyze our experience in the treatment of postoperative bleedings.

**Methods:** It is a retrospective study embracing the period 2014–2018 and includes patients with postoperative hemorrhagic complications after pancreatic surgery. The type of treatment, endovascular interventions, and outcome were analyzed.

**Results:** During the study period 524 patients underwent resection pancreatic surgery. Fifty-six of them (10.7%) developed postoperative hemorrhage: 35 (62.5%) had intraabdominal hemorrhage, 18 (32.1%) had intestinal hemorrhage, and 3 (4.4%) had a combination of the two types of hemorrhage. Overall, 14.3% (8) of complications developed within the first 24 hours postoperatively, and 85.7% (48) developed later than 24 hours. Most commonly (49%) postoperative hemorrhage developed after cancer resections. To control hemorrhage, a laparotomy was performed in 20 patients (35.7%) and endovascular surgery in 29 patients (51.8%). Among those who underwent endovascular treatment, 10 patients had surgery for recurrent hemorrhage: 3 after relaparotomy and 7 after endovascular surgery. From 29 patients who had endovascular treatment, 8 underwent stenting and 21 underwent embolization. The total lethality rate was 17.8% ( $n = 10$ ). Among the patients who underwent relaparotomy for hemorrhage control, 7 (35%) died; and among those who underwent endovascular surgery, 3 (10.3%) died.

**Conclusion:** Postoperative hemorrhage after pancreatic resections is a serious complication. Endovascular hemorrhage control is now the most effective and least invasive to control such hemorrhage. Endovascular surgery implementation resulted in decreased postoperative mortality.

# Endovascular Treatment of Postoperative and Posttraumatic Hepato-Pancreatic Hemorrhage

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**Introduction:** The aim of our study was to evaluate the results of diagnostic angiography and endovascular treatment of postoperative and posttraumatic hemorrhage in the hepato-pancreato-duodenal region.

**Methods:** All patients who had either postoperative or posttraumatic hemorrhage in a hepato-pancreato-duodenal region and admitted to two divisions of our academy during the period of 2006–2018 were included in the retrospective analysis. For the purpose of embolization, either coils or N-butyl cyanoacrylate (NBCA), Onyx, or gelfoam were used. In hemorrhage from pancreatic arteries, targeted vessel embolization was performed. In liver artery injury, proximal embolization was used.

**Results:** Forty patients were included in the study in total. Twelve patients were diagnosed with pancreatic intracystic hemorrhage caused by either its percutaneous or transgastric drainage. Six patients had splenic artery hemorrhage into a lumen of pancreatic enteroanastomosis, another 6 from arteria hepatica propria into a lumen of hepatic enteroanastomosis and/or intraabdominally, 4 from the superior mesenteric artery into a lumen of hepatic enteroanastomosis and/or intraabdominally, 8 hemobilia after percutaneous biliary drainage, 4 posttraumatic liver injuries after surgery in this zone. In all cases, angiography allowed the source of hemorrhage to be defined. Contrast extravasation was revealed in 17 patients and pseudoaneurysms in 12 patients. Indirect signs of hemorrhage took place in 6 patients.

In 9 patients with major visceral artery pseudoaneurysms, stent grafts were placed. In 2 cases of liver injuries, branches of the portal vein were embolized. Primary hemostasis was achieved in all cases. Complications developed in 2 patients postoperatively. One patient who had a splenic artery embolized with NBCA developed a splenic abscess (addressed with ultrasound-guided drainage). Recurrence of hemorrhage was registered for 4 (11.4%) patients: one was embolized, and the remaining 3 underwent emergency laparotomy. There were no fatalities in the postoperative period.

**Conclusion:** Endovascular techniques are effective in controlling postoperative and posttraumatic hemorrhage in the hepato-pancreato-duodenal region. These techniques reduce mortality and morbidity.

## Impending Rupture of a Traumatic Giant Pseudoaneurysm of the V2 Segment of the Vertebral Artery: A Successful Hybrid Approach and Outcome. A Vascular Surgeon View

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**Background:** Vertebral artery (VA) aneurysms are rare clinical findings, representing 1% of supra-aortic aneurysms. The most common cause of extracranial VA aneurysms (EVAA) is penetrating neck trauma, but they can also occur secondary to dissection, atherosclerosis, infection, collagen vascular diseases, and inherited connective tissue disorders. EVAA are very uncommon accounting for 0.5% of all aneurysms; they generally affect the most mobile segment, which is the V3 segment, followed by the V1 segment. The rupture of an EVAA can lead to catastrophic bleeding and pose a diagnostic and therapeutic challenge. VA injuries constitute less than 1% of all the vascular injuries and less than 1–6 % of all the vascular injuries in the cervical region. Penetrating VA injuries are rare and injuries were previously missed prior to the routine use of angiography in diagnosing penetrating neck injuries. Frank hemorrhage was the impetus for the decision for operative exploration at the onset.

**Case description:** Here we report the largest pseudo aneurysm reported in the literature. It was impending to rupture, arising from the second part of the right vertebral artery (V2) in a 35-year-old male. CT-angiography confirmed the presence of extracranial pseudoaneurysm involving the 2nd part of the right VA, measuring 10 × 7.5 cm<sup>2</sup>. The aim of this study was to focus on a very rare vascular injury that a vascular surgeon can encounter throughout his daily work and highlight the treatment options in an emergency situation, putting into consideration the availability of different tools. We went through a hybrid approach where the proximal parent vertebral artery was controlled with a 3-mm balloon (30 mm length), through a rapid right trans brachial access followed by deployment of two coils, but surgical exposure and ligation of the V3 part was mandatory due to refilling of the aneurysm through retrograde flow from the contralateral VA. The postoperative period was free of any cerebrovascular ischemic signs followed by recovery.

## REBOA is Effective in Reducing Intraoperative Blood Loss During C-Section in Cases of Abnormal Placenta

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**Background:** According to the WHO, post-partum hemorrhage (PPH) is the leading cause of maternal mortality in the world. Abnormally invasive placenta (a/in/percreta) is one of the main causes of PPH. It usually takes place in 1:500 to 1:2500 pregnancies. As the number of C-sections is increasing over recent years, the number of abnormally invasive placenta has increased. The average intraoperative blood loss during these C-sections is about 3–5 L and can reach 10 L to necessitate a massive blood transfusion. Around 75% of such operations end with hysterectomy. Resuscitative endovascular balloon occlusion of the aorta (REBOA) is now an option for blood loss prevention in cases of abnormally invasive placenta during C-sections. The aim of our study is to analyze all the cases of REBOA use in a single perinatal center.

**Methods:** This is a retrospective study covering the period of November 2018 to March 2019, and all the cases of REBOA used are included in the analysis. Diagnosis of abnormally invasive placenta was confirmed by preoperative ultrasound and MRI. Under epidural anesthesia, a radial artery was cannulated for invasive blood pressure monitoring, and a femoral artery was cannulated (8 Fr) under ultrasound guidance for REBOA catheter placement. For the procedures, a rescue balloon (Tokai Medical, Japan) was used in all cases. A deflated balloon was positioned above the aortic bifurcation under trans-lumbar ultrasound guidance. Once the C-section was done and the child removed, the balloon was inflated and metroplasty performed. After the operation, the sheath was removed by manual compression.

**Results:** Five patients underwent preventive REBOA. All the patients tolerated the procedure. Mean operative procedure time was 56 (48–67) minutes, occlusion time was 20 (16–29) minutes. Average blood loss was 620 mL (300–1000 mL). Fluid replacement therapy included  $1600 \pm 200$  mL of crystalloids, and no blood components were needed. No complications were recorded and all patients were discharged on postoperative day 5.

**Conclusion:** Preventive REBOA for abnormally invasive placenta is a safe and effective procedure for reducing intraoperative blood loss.

## First Experience of a Femoral Artery Catheterization for Potential REBOA During Inter-Hospital Transportation by HEMS in Russia

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**Background:** Resuscitative endovascular balloon occlusion of the aorta (REBOA) is now increasingly used for trauma management around the world. It is usually performed upon the patient's admission in the emergency room or operating room. However, prehospital and transfer REBOA have been recently described in the literature. Here we present the first Russian experience of prehospital endovascular resuscitation and trauma management implementation when a femoral artery was accessed for possible REBOA during the transportation of an unstable patient.

**Case description:** A 58-year old male involved in a road traffic accident was delivered to a rural trauma center in the Leningrad Region. On admission (about one hour after the injury), the following lesions were revealed: blunt chest trauma with multiple rib fractures on the left with pulmonary contusions, unstable pelvic fractures, multiple left femur and tibia fractures.

The patient was intubated, and a diagnostic peritoneal lavage was performed (negative) followed by external pelvis and left femur fixation. Hemoglobin level dropped from 11 to 9 g/dL and continued decreasing. Blood transfusion was limited by 2 units of packed red blood cells due to a lack of blood in the rural facility. Blood pressure (BP) remained unstable with systolic BP not higher than 100–110 mm Hg while norepinephrine was given at 0.2 mcg/kg/min.

Twelve hours later, there was a significant loss in vitals: hemoglobin level decreased to 8 g/dL and then to 7.2 g/dL with systolic BP around 90 mm Hg, likely due to persistent pelvic bleeding. A decision was made to transfer the patient to a Level 1 trauma center by helicopter.

Due to the patient's instability (norepinephrine 0,14 mcg/kg/min, BP 100/70), the decision was made to place a deflated REBOA catheter into the aortic Zone III and inflate it in case of a sudden loss of systemic BP. Supposed transport time was 50–60 minutes. On an ICU bed, the 11 Fr introducer was placed into right femoral artery under-ultrasound guidance. Due to the relative stabilization of the patient immediately before transport, no catheter was inserted and a sheath was used for BP monitoring. Time for the sheath placement, which was performed by a helicopter emergency medical service (HEMS) anesthetist, was 9 minutes. Total transportation time was 48 minutes.

During transportation, the patient remained vitally stable (BP not less than 95/70), so there was no need for a REBOA-catheter insertion. At the Level 1 trauma center, a massive transfusion protocol was initiated. Thromboelastography showed normal coagulation. No severe acidosis was found in blood gases (pH 7.35; BE-2). A small correction of an external pelvis fixator was performed by a skilled orthopedic surgeon. Femoral artery access was removed by manual compression with no complications. The patient was then stabilized with uneventful recovery.

**Conclusions:** Preventive femoral artery cannulation prior to transport of a hemodynamically unstable patient allowed minimizing risks of fatal non-compressible bleeding en route. In this case, artery cannulation at the most crucial and sophisticated stage was made in a relatively calm ICU setting by a HEMS crew. REBOA catheter insertion was wisely delayed to the point of potential BP fall due to transport exposure factors. In addition, artery cannulation can be used for invasive BP measurement and repeated blood gas analysis.

## Arterial Embolization for Recurrent Gastrointestinal Bleeders in Elderly Patients

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**Background:** Endoscopic hemorrhage control is a gold standard in the treatment of peptic ulcers accompanied by gastrointestinal (GI) bleeding. Saint Petersburg data shows a lethality rate of 5% in 2016 for GI bleeding, and post-operative lethality is 8.5%. As endovascular techniques are developing, arterial embolization (AE) is an alternate option if conservative treatment with endoscopy fails, especially in high-risk patients. The aim of our study was to analyze the effectiveness of AE in elderly patients with GI bleeding.

**Methods:** This is a retrospective study of consecutive patients admitted to our facility with recurrent GI massive bleeding who underwent angiography and AE for hemorrhage control during the period of 2013–2017. The severity of physiology abnormalities was assessed using the APACHE II scale, the severity of GI bleeding was assessed using Forrest's classification.

**Results:** A total of 20 patients met the inclusion criteria. The median age was  $62.7 \pm 14.8$  years. According to APACHE II, 14 patients had a score of 26 or more, and 4 patients had a score of 20–25. Upon angiography, the bleeder was localized on the stomach small curvature in 14 cases, the back duodenum wall in 6 patients. Endoscopy revealed callous ulcers more than 2 cm in diameter in 8 cases. According to the Forrest classification, patients were distributed as follows: IA, 2; IB, 3; IIA, 10; IIB, 5. In 3 cases, there was a failure of endoscopic hemostasis. Bleeders were embolized by either a combination of glue and microcoils ( $n = 10$ ), or glue ( $n = 3$ ), or microcoils ( $n = 4$ ), or a combination of microcoils and gelfoam ( $n = 3$ ). Technical and clinical (hemorrhage control) success of AE was achieved in 95% of cases ( $n = 19$ ). One patient had a 60%-stenosis of a proximal part of the gastrosplenic trunk making selective catheterization hardly possible. No recurrent bleedings were registered. Three patients died in the postoperative period (15% lethality rate) due to severe co-morbidities and heart failure.

**Conclusion:** AE is a feasible option for GI hemorrhage control, especially in elderly patients with peptic ulcers. Additional studies are warranted to define an optimal cohort of patients, indications, a type of AE, and an optimal embolizing technique and agent.

## Pelvic Angiography for Polytrauma Patients: A Single-Center Experience

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**Background:** The aim of our study was to evaluate the effectiveness of pelvic angiography (PA) followed by internal iliac artery (IIA) embolization to control bleeding in cases with polytrauma and severe unstable pelvic fractures.

**Methods:** A retrospective study of all the polytrauma patients with unstable pelvic fractures who were admitted to our trauma center and underwent PA during the period of 2014–2018 was performed. Time of transportation to our hospital, the severity of trauma (according to the ISS), door-to-angio time, duration of PA, results of PA, and transfusion requirements were recorded and analyzed. As the first stage of care, external fixation of pelvic ring fractures was performed. Then, if instability maintained or a patient deteriorated pelvic packing was done. As a next step, PA was done to rule out an arterial source of bleeding.

**Results:** Fifteen patients were enrolled in this study. Most of them (74%) were male. Among these, there were 7 falls (46.7%), 7 road-traffic collisions (46.7%), and 1 was compressed by a heavy object (6.6%). According to the Tile classification, there were 1 type A, 6 type B, and 8 type C fractures. Average time of transportation to a hospital was  $67.9 \pm 14.8$  minutes. The average ISS score was  $35.67 \pm 10.77$ . According to the H.C. Pape classification (2005), there were 5 patients with borderline conditions and 10 with unstable hemodynamics.

All patients underwent external pelvic fixation. Among them, five patients underwent pelvic packing and the others were transferred immediately to an angiosuite. The REBOA procedure was performed in zone III for temporary hemorrhage control only once. Upon PA, arterial “blush” and sharp “cut-off” were found in 5 (33%) and 3 (20%) cases, respectively. These patients then underwent a therapeutic endovascular intervention. The other 7 patients only had diagnostic PA.

Median door-to-angio time was  $323.5 \pm 164.4$  minutes. Duration of the procedure was between 30 and 85 ( $47 \pm 18$ ) minutes. Selective and non-selective embolizations were performed in 6 and 2 cases, respectively. Transfusion requirements were  $2.80 \pm 0.67$  units of packed red blood cells during the first 24 hours in ICU. Twenty-four-hour survival was 80% (12 patients) and total survival rate was 60% (9 patients). Median stay-in-hospital time was  $37.4 \pm 14.1$  days.

**Conclusion:** Angiography allowed the recognition of an arterial source of bleeding in every second polytrauma patient. In all cases, embolization was effective in controlling bleeding and there was no recurrence of bleeding until discharge.

## Uterine Artery Embolization for Abnormally Invasive Placenta: An Experience of Collaboration Between a Perinatal and a Regional Center

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**Background:** Post-partum hemorrhage (PPH) is a blood loss of more than 10% of circulated blood (or 500 mL) during a vaginal birth or more than 1,000 mL during a Caesarean delivery (physiologic hemorrhage). A blood loss of 10–30% is pathologic, and more than 30% is massive. The latter occurs in 5% of all deliveries. Massive PPH is an important source of maternal mortality (15–25% of cases). To prevent PPH different techniques were proposed, and one of them is uterine artery embolization (UAE). The aims of UAE are: 1) uterine preservation, 2) reducing blood loss, 3) stable delivery, 4) decrease of maternal mortality. We investigated the effectiveness of this method to control PPH.

**Methods:** This is a retrospective study summarizing all patients admitted to our hospital with abnormally invasive placenta and underwent a hybrid operation (UAE and C-section) from June 2015 to March 2019. The type of operations, anesthesia, access, and operative time were recorded.

**Results:** Forty-one patients were analyzed. Every woman underwent a hybrid operation. Median parameters were: age 33.1 years, gestations 3.8, deliveries 2.9, and gestational age 37.5 weeks. Thirty-two patients were intubated, and the rest underwent spinoepidural anesthesia. Different vascular accesses were used for operations: both femoral arteries in 25 cases (61%), one femoral artery in 3 cases (7%), and a brachial artery in 13 cases (32%). Operative time was 184.8 (105–301) minutes and median blood loss was 1282 (500–5,000) mL. There were no complications and no cases of maternal mortality registered. In only one case, extirpation of the uterus was performed on the 2<sup>nd</sup> postoperative day.

**Conclusion:** The hybrid approach (angiography + C-section) for childbirth complicated by abnormally invasive placenta is an effective and safe technique, which, however, necessitates a multidisciplinary approach (anesthetists, perfusionists, Ob&Gyn, neonatologists, IR, urologist, nurses).

# Our Experience in Implementation of Endovascular Techniques in Vascular Trauma

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**Background:** The aim of this study was to present our experience in endovascular procedures performed for vascular injuries.

**Methods:** This is a retrospective study embracing the period of June 2005 to March 2019. All the endovascular procedures for trauma performed in our center during this period were analyzed. The type of operation was also recorded. Embospheres, poly(vinyl alcohol), coils and microcoils, gelatin sponge, and glue were used for the embolization of bleeders. In arterial perforations and aortic ruptures, a stent graft was implanted.

**Results:** Eighty-nine patients were included in this study. The median age was  $56 \pm 19$  years (53 male, 36 female). They underwent 94 endovascular procedures. Embolizations were performed for postoperative hemorrhage control of urologic patients, after ear, nose and throat and gynecology operations, and GI bleeders in 13, 12, 11, and 9 patients, respectively. Other bleeders were embolized in 4 patients. Microcoils were super-selectively placed in 3 patients with perforations of coronary artery branches. Twenty patients had percutaneous coronary intervention-associated coronary artery perforations which caused hemopericardium. Seventeen of them, 2 patients with blunt traumatic aortic injuries, 13 patients with femoral/brachial puncture-site bleeding, and 5 patients with iatrogenic iliac artery perforations were successfully treated with stent-graft placement. The total lethality rate was 2.2% (2 patients). One patient died a few hours after thoracic endovascular aortic repair. Another patient died the day after stent-graft placement in an injured coronary artery.

**Conclusion:** Endovascular procedures in different vascular injuries are effective and safe.

# Endovascular Resuscitation with Aortic Balloon Occlusion in Pediatric Trauma: A Case Report

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**Background:** Resuscitative endovascular balloon occlusion of the aorta (REBOA) is currently evolving and its use for trauma and resuscitation management in adults is increasing. There is, however, no detailed data published on its use in pediatric trauma. We describe a case of REBOA for traumatic hemorrhagic instability in a pediatric patient according to the concept of Endovascular resuscitation and Trauma Management (EVTm) at Örebro University Hospital in April 2019.

**Case description:** An 11-year-old boy arrived at the emergency room by air ambulance after a motor vehicle accident with a positive seat-belt sign. During transport, due to total hemodynamic collapse, cardiopulmonary resuscitation was initiated with a return of spontaneous circulation though continued episodes of bradycardia. Bilateral common femoral artery (CFA) access (8 Fr) was gained in the emergency room and REBOA was placed uninflated in Zone I by landmark guidance. The patient was rapidly transferred to the operating room for an explorative laparotomy. A systolic blood pressure (SBP) of 40 mm Hg was registered on arrival to the surgical suite and total REBOA in Zone I was performed for 7 minutes. Massive transfusion and damage control surgery were performed stopping a massive mesenteric arterial hemorrhage, the patient stabilized with an SBP of around 110 mm Hg. Both CFA accesses were closed by manual compression. There were no complications related to the use of REBOA. The patient is currently undergoing abdominal reconstructive surgery.

**Conclusion:** REBOA for endovascular resuscitation may be an additional method for temporary hemodynamic stabilization in pediatric patients and was in this specific case used instead of thoracotomy for hemodynamic instability.

# Irreversible Sudden Cardiac Arrest in Potential Transplant Surgery: Problems and Perspectives

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**Background:** Extracorporeal membrane oxygenation (ECMO) is used more and more often around the world for the treatment of critically unstable patients. In some cases, ECMO is the only way to save patients' lives. It is used for sudden cardiac arrest (SCA) at the prehospital stage of care when standard cardiopulmonary resuscitation (CPR) is not effective. However, when invasive lifesaving techniques (ECMO-CPR, balloon contrapulsation) are also ineffective, an ultimate possibility of donor organ transplant surgery should be always kept in mind for ongoing ECMO (according to a brain death protocol) and after the withdrawal of care for futility (ECMO-saving perfusion, ECMO-SP).

**Methods:** All patients with ongoing CPR (Lucas-2) admitted to our emergency department during the period of October 2017–March 2019 were included in this study. A decision for ECMO-CPR was made by an ECMO-team leader after appropriate diagnostic tests (angiography, CT, ultrasound, ECG, etc). In 20 minutes after biological death was assured, the perfusion was initiated. If the return of circulation and cardiac rhythm was achieved using ECMO-CPR, confirmation of brain death was performed using standard criteria. This study was approved by the local Ethical committee.

**Results:** Thirty-four patients were admitted to our emergency department during the study period. Sixteen potential donors met the inclusion criteria. The median age was  $48.3 \pm 4.5$  years. Nine potential donors were excluded at a phase of cannulation and ECMO initiation due to technical problems, massive bleeding, cannulas migration or oxygenator thrombosis. An additional four donors were excluded due to ineffective perfusion, serologic and histologic exclusion criteria. In two cases with a return of cardiac rhythm, brain death was diagnosed. The ECMO-SP protocol allowed ten kidneys and two livers to be transplanted with good clinical results (one after ECMO-SP, one from a brain-dead donor).

**Conclusions:** ECMO-CPR is effective in patients with cardiac arrest. Time limits and laboratory markers have to be promptly followed. ECMO centers are needed for taking care of patients with SCA. Those patients have to be immediately transported from the scene to such centers. If any criteria of irreversible brain injury are met, then ECMO-CPR can be used as a bridge for organ transplantation. Anoxic perfusion using ECMO-CPR can be initiated immediately after the termination of CPR. It helps to decrease the time of the "no-touch" period for brain death criteria diagnosis (the same as the apnea test).

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## Feasibility of Blind Versus Ultrasound-Guided Vascular Access and REBOA on Board of a Medical Helicopter in a Hemorrhagic Ovine Model

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**Background:** The aim of this study is to evaluate the feasibility of en route resuscitative endovascular balloon occlusion of the aorta (REBOA) on board of a helicopter.

**Methods:** Six sedated male sheep (weighing  $47.5 \pm 4.0$  kg) were placed on a spineboard, underwent a controlled venous hemorrhage until the systolic arterial pressure (AP) dropped to  $<90$  mmHg, and were placed into a low capacity Eurocopter EC-350. During a 30-minute normal flight, every animal underwent blind (left side) and ultrasound-guided (US) (right side) vascular access (VA) to the femoral artery followed by REBOA: the first catheter into zone I and the second into zone III. The 7-Fr Rescue (Japan) and the 10-Fr MIT (Rus) balloons were used without primary wire insertion. Every VA procedure was limited to 10 minutes. In case of blind VA failure, an alternate US-puncture was also available at the left side. Six experienced flight anesthetists previously trained in REBOA with one assistant were enrolled in the study. VA and REBOA catheter placement (confirmed by X-Ray) success rate and timing were recorded.

**Results:** Nine of 12 VAs (75%) were successful: 1/6 blind punctures compared to 8/9 US-punctures ( $p = 0.011$ ). However, correct wire insertion and sheath placement was performed in 1/6 animal in the blind group and only in 6/9 animals in the US-group ( $p = 0.119$ ). It took 65 (interquartile range, 30–242) seconds for US-puncture and 4 minutes on average to get the sheath in. Among 9 VAs, there were 2 REBOA failures (1 ruptured balloon [MIT] and 1 mistaken vena cava placement primarily recognized by a sudden drop of AP and later confirmed by X-Ray). Overall, 5/7 balloons were placed in the desired position: 4/5 in zone I and 1/2 in zone III. The average time for a successful REBOA procedure was 5.0 (4.6–9.3) minutes (1 min after sheath placement).

**Conclusion:** Our study demonstrates the potential feasibility of the en route REBOA which can be performed within 5 minutes. US-guidance is critically important to achieve en route VA.

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## Battlefield Extracorporeal Cardiopulmonary Resuscitation (ECPR) for Out-of-Hospital Cardiac Arrest: A Pilot Feasibility Study on Large Animals

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**Background:** The aim of this study is to evaluate the feasibility of pre-hospital extracorporeal cardiopulmonary resuscitation (E-CPR) in the military exercise setting simulating a modern armed conflict.

**Methods:** Two sedated 40-kg *Sus scrofa* were enrolled. After controlled removal of 1L of blood, potassium chloride was administered to achieve cardiac arrest (CA). A minute after the CA was confirmed by ultrasound, an external compression device was applied for ongoing CPR. The animal was then transported to Role 1. Both the femoral artery (10 Fr) and vein (18 Fr) were cannulated and E-CPR was immediately initiated using a portable perfusion device (PEVK, TransBioTech.Ltd/Skolokovo). Once the circuit was stabilized, the animal was then evacuated by a helicopter to Role 2 where the study was terminated.

**Results:** Both animals developed persistent CA and were transported to Role 1. In the first animal, in 25 min after CA both artery and vein were cannulated and E-CPR initiated with a blood flow rate (BFR) of 2.5 L/min. The animal tolerated a 15-min flight well and stayed alive for 4 hours without return of spontaneous circulation. However, abdominal compartment syndrome was developed due to severe blood loss (hemoglobin level decreased from 10.2 to 3.6 to 1.3 g/dL), shock (mean arterial pressure decreased from 97 to 47 to 34 mmHg) and extensive fluid replacement (9 L), which caused a drop of the BFR to 400 mL/min. After a decompressive laparotomy was performed, the BFR restored

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to 1.5 L/min. In the second swine, femoral vein cannulation was successful 17 min after CA; however, 2-hour multiple attempts to cannulate peripheral arteries (both femoral and carotid) were unsuccessful due to spasm and hypotension, and, finally, open aortic cannulation allowed launching the circuit. However, due to extensive bleeding, the study was terminated for futility.

**Conclusion:** Our study demonstrates the potential feasibility of battlefield E-CPR, but it is futile without aggressive damage control resuscitation.

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