Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) and Selective Aortic Arch Perfusion (SAAP) in Resuscitation

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Resusitech, Inc.

State of the Future of Resuscitation
Take Heart America
Oakland, CA
September 28, 2018
Disclosure

Inventor on patents for Selective Aortic Arch Perfusion assigned to the University of North Carolina at Chapel Hill.

Department of Defense grant funding.

Co-Founder of Resusitech, Inc., a medical device company developing resuscitation technologies.
Endovascular-Extracorporeal Resuscitation Era

Momentum from two different directions:

**Endovascular Hemorrhage Control in Trauma / Arrest**
- REBOA
- SAAP
- EPR

**Extracorporeal Perfusion in Medical Cardiac Arrest**
- ECMO / E-CPR
- SAAP
- Impella

An “Interventional Toolkit” for Resuscitation in both Trauma and Medical Cardiac Arrest
Aortic Interventions for Resuscitation

REBOA – Resuscitative Endovascular Balloon Occlusion of the Aorta

SAAP – Selective Aortic Arch Perfusion

Pressure Catheters – AoP monitoring & intra-Ao drugs

Impella – Interventional device inserted via the aorta

EPR – Emergency Preservation and Resuscitation
Aortic Balloon Catheter-Based Interventions for Resuscitation

REBOA – Resuscitative Endovascular Balloon Occlusion of the Aorta

SAAP – Selective Aortic Arch Perfusion
Perfusion is the Key
to achieving
Return of Spontaneous Circulation (ROSC)
REBOA

“Aortic Occlusion”
REBOA in Trauma

Arterial hemorrhage control below the balloon

Increased SVR

Increased MAP

Vital organ perfusion support in the setting of a non-arrested heart

Figure 1. Aortic zones related to REBOA. Zone I extends from the origin of the left subclavian artery to the celiac artery and is a potential zone of occlusion. Zone II extends from the celiac artery to the lowest renal artery and is a no-occlusion zone. Zone III exists from the lowest renal artery to the aortic bifurcation. REBOA in this zone may provide particular utility for instances of pelvic and junctional femoral (contralateral) hemorrhage.
Zone I REBOA
Zone III REBOA
Zone I REBOA in Traumatic Cardiac Arrest
Aortic balloon occlusion *alone* in “true” cardiac arrest does not increase central AoP.

CPR chest compressions are the driver to generate myocardial perfusion.

CPR in hypovolemic state – largely ineffective.

Intravascular volume must be normalized.
Zone I REBOA in Trauma Cardiac Arrest

**Interventions:**

- Distal hemorrhage control
- Support aortic pressure during CPR
- Aortic pressure monitoring during CPR
- Intra-aortic epinephrine or other drugs
Zone I REBOA in Medical Cardiac Arrest
Zone I REBOA in Medical Cardiac Arrest

REBOA may improve AoP & CPP generated by CPR chest compressions

AoP monitoring could be used to guide therapy

Intra-aortic delivery of drugs
Zone I REBOA in Medical Cardiac Arrest


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Original Contribution

The role of resuscitative endovascular balloon occlusion of the aorta (REBOA) as an adjunct to ACLS in non-traumatic cardiac arrest

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b Queen Elizabeth University Hospital, Department of Vascular Surgery, Glasgow, United Kingdom
c Johns Hopkins Medicine, Department of Emergency Medicine, Baltimore, MD, United States
Zone I REBOA in Medical Cardiac Arrest

Case Reports

1996

Haemodynamic effects of descending aortic occlusion during cardiopulmonary resuscitation

Charles D. Deakin, David J. Barron

Department of Anaesthetics, Southampton General Hospital, Tremena Road, Southampton SO16 6YD, UK

Department of Cardiothoracic Surgery, Southampton General Hospital, Tremena Road, Southampton SO16 6YD, UK

Resuscitation

2009

Intraaortic balloon occlusion during refractory cardiac arrest. A case report

Emre Aslanger, Ebru Golcuk, Huseyin Oflaz, Akar Yilmaz, Fehmi Mercanoglu, Zehra Bugra, Berrin Umman, Yilmaz Nisanci

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Zone I REBOA in Medical Cardiac Arrest

Hemodynamic Effects of the Intra-aortic Balloon Pump During Experimental Cardiac Arrest

CHARLES L. EMERMAN, MD,* ALFRED C. PINCHAK, MD, PhD,† JOAN F. HAGEN, BA,† DONALD HANCOCK, AE†

Nine canines – KCl arrest
Immediate mechanical CPR
IABP timed with CPR
Balloon inflation during CPR diastole

CPP mm Hg
w/ IABP 18.9 ± 10.3
w/o IABP 10.9 ± 10.5


FIGURE 4. Coronary perfusion pressure with and without the IABP.
Zone I REBOA in Medical Cardiac Arrest

14 swine – 8 min untreated VF, randomized into 2 groups

Cross-over: --- 5 min ------- 5 min ------- 5 min ------- 5 min -----→

(n = 7)      w/ balloon     w/o      w/      w/o
(n = 7)      w/o balloon    w/      w/o      w/

First Period       Second Period

TABLE 1. Hemodynamic Parameters With and Without Occlusion Balloon

<table>
<thead>
<tr>
<th></th>
<th>First Period With Balloon Mean ± SD (CI)</th>
<th>First Period Without Balloon Mean ± SD (CI)</th>
<th>Second Period With Balloon Mean ± SD (CI)</th>
<th>Second Period Without Balloon Mean ± SD (CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAP</td>
<td>73.79 ± 21.04 (61.65–85.93)</td>
<td>40.93 ± 10.16 (35.08–46.78)</td>
<td>50.71 ± 22.9 (37.49–63.93)</td>
<td>24.57 ± 10.12 (18.74–30.4)</td>
</tr>
<tr>
<td>CorPP</td>
<td>29 ± 18.06 (18.57–39.43)</td>
<td>10.21 ± 5.03 (7.32–13.1)</td>
<td>16.86 ± 15.83 (7.72–26)</td>
<td>1.64 ± 2.98 (−0.09–3.37)</td>
</tr>
<tr>
<td>CPP</td>
<td>39.71 ± 19.45 (28.48–50.94)</td>
<td>12.54 ± 6.58 (8.74–16.34)</td>
<td>21.96 ± 18.05 (11.55–32.37)</td>
<td>1.21 ± 5.56 (−2.01–4.43)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; SAP, systolic arterial pressure; DAP, diastolic arterial pressure; CorPP, coronary perfusion pressure.

NOTE. Values are expressed in mm Hg. In all cases, the differences between periods with and without occlusion balloon are statistically significant using the Wilcoxon test (P < .0001).

Zone I REBOA in Medical Cardiac Arrest

FIGURE 6. Cerebral perfusion pressure values during the study in 14 subjects. *Basal period; †no intervention period; ‡first period with balloon; §first period without balloon; ¶second period with balloon; ‖second period without balloon.
Zone I REBOA in Medical Cardiac Arrest

A few case reports suggesting beneficial effect

Laboratory studies:

Several studies showing improved hemodynamics:

CPP, circulation time, ETCO₂

Large variance in response to aortic occlusion

Clinical trials are being pursued
SAAP

Aortic Occlusion

+ “Extracorporeal Perfusion”
Selective Aortic Arch Perfusion is a cardiac arrest resuscitation technique that involves the blind insertion of a large-lumen balloon occlusion catheter into the descending thoracic aortic arch via a femoral artery. With the balloon inflated, the heart and brain are relatively isolated for resuscitative perfusion with an oxygen-carrying fluid to promote restoration of spontaneous circulation (ROSC) by the heart while protecting the brain from further ischemic insult.

From the Departments of Emergency Medicine, Surgery, and Anesthesiology, University of North Carolina at Chapel Hill School of Medicine.

Received for publication September 6, 1991. Revision received February 24, 1992. Accepted for publication March 23, 1992.


Study objectives: To demonstrate the technique of selective aortic arch perfusion during cardiac arrest and to observe the hemodynamic effects of volume infusion and aortic epinephrine administration.
SAAP in Traumatic Cardiac Arrest
Selective Aortic Arch Perfusion for Hemorrhage-Induced Cardiac Arrest


**Trauma / Hemorrhagic Shock:**

Aortic balloon occlusion to limit abdominal/pelvic blood loss caudal to the balloon (*functional aortic cross-clamp*)

Perfusion of the heart & brain with an oxygenated solution (HBOC, fluorocarbon, whole blood) to ROSC & to restore intravascular volume rapidly

**Intra-aortic administration**

- Epinephrine / vasoactive agents
- Ischemia-reperfusion agents
- Hemostatic products

*Temperature regulation (??)*
Selective aortic arch perfusion with hemoglobin-based oxygen carrier-201 for resuscitation from exsanguinating cardiac arrest in swine

James E. Manning, MD; Laurence M. Katz, MD; L. Bruce Pearce, PhD; D. Neil Batson, BS; Shane L. McCurdy, BS; Maria S. Gawryl, PhD; Christopher C. Baker, MD

Thoracic aortic occlusion produced by inflation of the SAAP catheter balloon provides a functional aortic cross-clamp that has the obvious potential for limiting further blood loss from vascular injuries below the diaphragm. The balloon was
SAAP – 800ml/min (10 ml/kg/min)
SAAP
in Medical Cardiac Arrest
Selective Aortic Arch Perfusion for Medical Cardiac Arrest/Sudden Death


**Medical Cardiac Arrest:**

Aortic balloon occlusion allows relatively isolated perfusion of the heart and brain

Heart and brain perfusion with an oxygen-carrying fluid
- Hemoglobin-based (HBOC)
- Fluorocarbon emulsion (PFC)
- Blood (allogeneic / autologous)

**Intra-aortic drug administration**
- Epinephrine / vasoactive agents
- Ischemia-reperfusion agents
- Hemostatic products

**Rapid hypothermia induction**
Generates “supra-normal” myocardial blood flow in the non-beating heart

Left Ventricular Myocardial Flow

- Control
- NP-SAAP with CPR
- NP-SAAP without CPR
- PD-SAAP with CPR

Regional flow (ml/min/100 gm)

Pre-Arrest Baseline
CPR Alone
SAAP
Initial perfusion of the heart & brain with an oxygen-carrying fluid:

- Hemoglobin (HBOC)
- Fluorocarbon (PFC)
- Blood (allogenic)

If ROSC is achieved with adequate cardiac function, balloon is deflated with observation for potential decompensation.
Selective Aortic Arch Perfusion — transition to — ECMO

SAAP
Exogenous oxygen carrier

SAAP
Autologous blood

Perfusion device
Selective Aortic Arch Perfusion — transition to — ECMO
Selective Aortic Arch Perfusion — transition to — ECMO

Partial V-A ECMO via SAAP catheter

Femoro-femoral V-A ECMO
SAAP versus directly to ECMO / E-CPR

Portability
- SAAP could be done with less complex equipment
- Created with the prehospital setting in mind

Timing in resuscitation
- No delay in initiation to allow ACLS to fail

Time to initiation of perfusion
- Only requires arterial catheter to begin perfusion support

Discontinuation
- Could be discontinued without need for surgery

Complications
- Potential for aortic injury, distal ischemia
Integration of REBOA & SAAP in Trauma Resuscitation
REBOA transition to SAAP & ECMO
“Trauma Resuscitation”

Sequential Interventions:
- starting with REBOA or SAAP, as appropriate
- transition to partial or full V-A ECMO, if needed
Integration of REBOA & SAAP in Medical Resuscitation
REBOA/SAAP transition to ECMO
“Medical Cardiac Arrest Resuscitation”

Sequential Interventions:
- starting with REBOA or SAAP, as available
- transition to partial or full V-A ECMO, as needed

No ROSC or ROSC but Unstable
Resuscitation Medicine

Key Concept: The “Chain of Survival”

Early Recognition & Activation (911)

Early CPR

Rapid Defibrillation

ACLS & Transport

Post-Resuscitation ICU/Neuro Care
Resuscitation Medicine

Key Concept: A New Link in the “Chain of Survival”

Early Recognition & Activation (911)

Early CPR

Rapid Defibrillation

ACLS & Transport

Endovascular Extracorporeal

Post-Resuscitation ICU/Neuro Care
Resuscitation Medicine

When one or more links in the “Chain of Survival” is Weak!

Early Recognition & Activation (911)

Endovascular / Extracorporeal Resuscitation Interventions

Early CPR

Rapid Defibrillation

ACLS & Transport

Post-Resuscitation ICU/Neuro Care
Thank You!