Monitoring Microvascular Blood Flow During Hemorrhage and Resuscitation

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Introduction

Microvascular blood flow is critical to survival.[1]

Organismal survival depends on tissue survival which depends on cell survival.

Cell survival depends on delivery of O_2 and nutrients to cells.

Delivery to cells depends on microvascular blood flow (arterioles, capillaries, venules).

Clinically, macrovascular cardiovascular indicators are monitored (blood pressure, heart rate, cardiac output); microvascular flow is not.

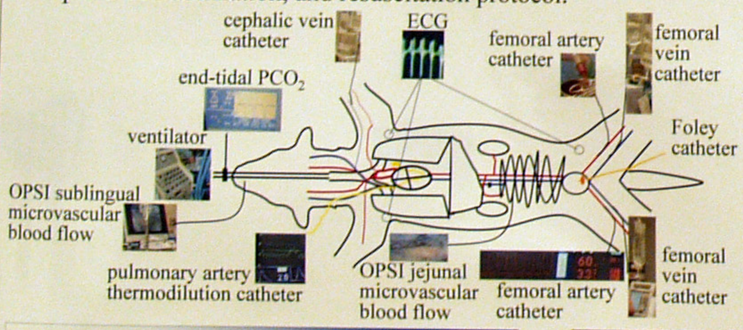
Technology now exists allowing real time microvascular blood flow imaging without dyes or radioactive labeling.

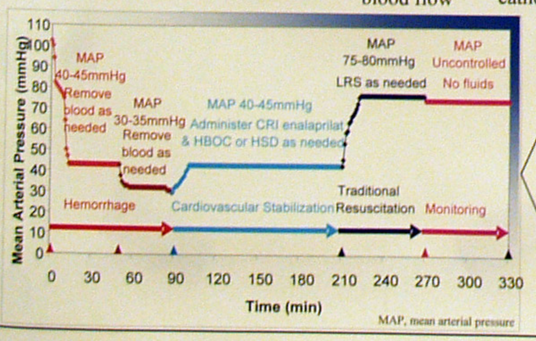
Microvascular blood flow is often not indicated by macrovascular variables.[2,3]

We are investigating the use of orthogonal polarization spectral imaging (OPSI) based microvascular blood flow monitoring in a hemorrhage and resuscitation study. We recorded imagery from a non-invasively accessible site (sublingual surface) and an invasively accessible site (jejunal mucosa). If real time microvascular blood flow can be reliably imaged, this technology may eventually become clinically useful.

Methods

8 anesthetized (thiopental infusion, cephalic vein), ventilated (end-tidal PCO_2 30-35 mmHg for arterial PCO_2 35-40 mmHg at baseline), instrumented, purpose bred hound dogs subjected to pressure titrated severe hemorrhage, low-pressure stabilization, and resuscitation protocol.

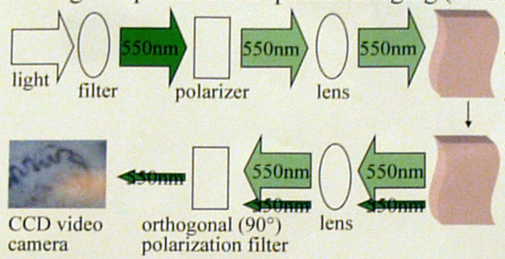




90 min Hemorrhage
120 min Cardiovascular Stabilization: 0.01 mg/kg/hr enalaprilat plus one of two fluids: 1) hemoglobin based oxygen carrier (HBOC) for MAP=40-45mmHg, n=5 or 2) 7.8% hypertonic saline dextran (HSD) for MAP=40-45mmHg, n=3
60 min Traditional Resuscitation: lactated Ringer's (LRS) for MAP=75-80mmHg
60 min Monitoring: no fluids
Euthanasia at minute 331

Methods (continued)

Orthogonal polarization spectral imaging (OPSI) of microvascular perfusion

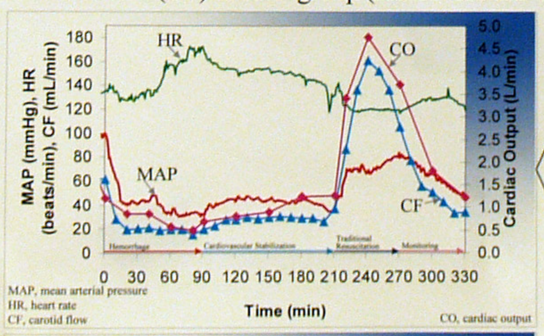


- hemoglobin absorbs 550nm light → acts as contrast agent
- 90% reflected off surface → still polarized (glare)
- 10% deeper penetration → multiple scatter events → reflected depolarized (image)

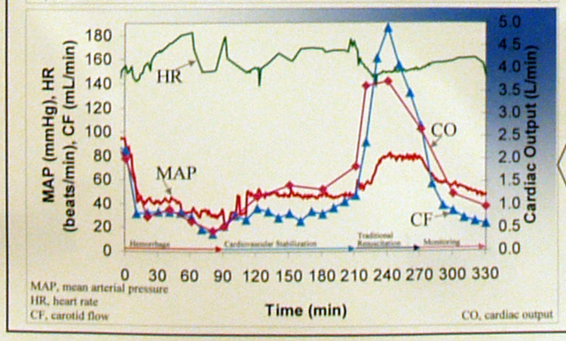
1. 1 min of sublingual and jejunal microvascular flow recorded every 10 min.
2. Recorded microvascular flow video examined with TMPGEnc 3.0 Xpress.
3. ≥10 sec sections of clearly visible microvascular structure sought in each recording.
4. Eventual scoring plan for each ≥10 second section
   a. Flow score: no flow (0), lower than baseline flow (1), same as baseline flow (2), or higher than baseline flow (3)
   b. Vessel score: fewer than baseline visible vessels (1), same as baseline visible vessels (2), or more than baseline visible vessels (3)

Results

Mean Arterial Pressure (MAP), Heart Rate (HR), Cardiac Output (CO), & Carotid Flow (CF) in each group (macrovascular cardiovascular indicators)



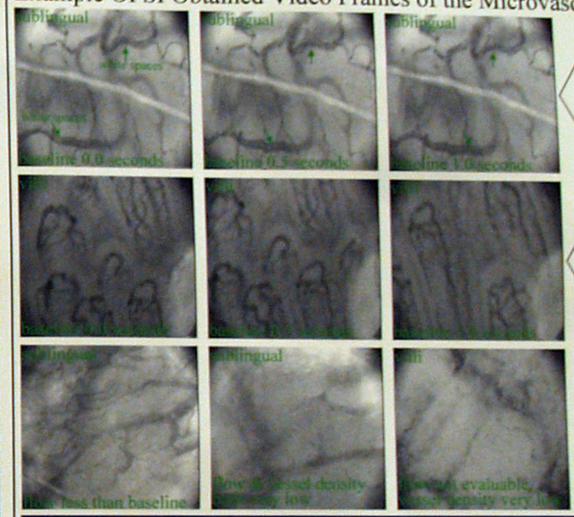
Average Values in HBOC recipients, n=5
1 death 117min into Cardiovascular Stabilization (minute 208)
Remaining 4 euthanized at minute 331
Rise in HR and fall in MAP and flows (CO and CF) during Hemorrhage
Maintained low flows during Cardiovascular Stabilization
Dramatic rise in flows during Traditional Resuscitation
Declining flows and MAP during Monitoring



Average Values in HSD recipients, n=3
1 death 9min into Cardiovascular Stabilization (minute 100)
Remaining 2 euthanized at minute 331
Rise in HR and fall in MAP and flows (CO and CF) during Hemorrhage
Low but rising flows during Cardiovascular Stabilization
Dramatic rise in flows during Traditional Resuscitation
Declining flows and MAP during Monitoring

Results (continued)

Example OPSI Obtained Video Frames of the Microvasculature



Motion and focus issues were prevalent. Microvascular flow and/or vessel density was decreased by hemorrhage, generally most difficult to clearly assess during low-pressure stabilization, and increased during resuscitation.

Discussion

- Microvascular blood flow responses can be monitored.
- Motion and focus issues can be prevalent.
- Motion and focus issues dramatically increase the amount of prep time required before any retrospective video analysis can be carried out.
- Sublingual microvascular flow assessment looks like it will be feasible at all time points from which a video segment without motion and focus issues can be obtained.
- Even putting aside motion and focus issues, jejunal villus microvascular flow assessment looks like it is going to be quite difficult when there is no hemodilution. This is because sufficient red cell density exists in the villus vessels at early time points that the vessels appear as solid dark structures, making it quite difficult to determine if the contained red cell mass is flowing or not.
- Both sublingual and jejunal villus microvascular vessel density, however, appear likely to be assessable at all time points.

References

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