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Anesthetic Management During Minimal Invasive Liver Surgery

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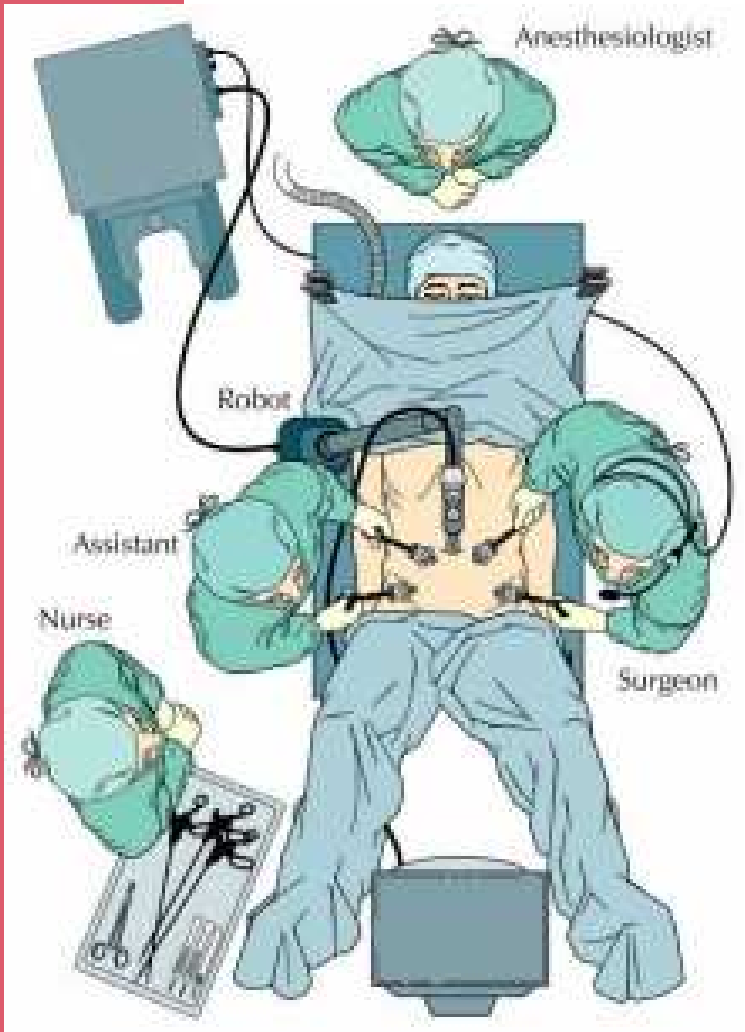

Anesthetic Considerations

Surgical Considerations

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Risk Factors During Laparoscopic Surgery

- **Pneumoperitioneum.**
- **Patient position.**
- **Surgeon's expertise and experience.**
- **Duration of laparoscopy.**
- **Unsuspected visceral injury.**
- **Difficulties in evaluating blood loss.**

Although minimal invasive, prolonged laparoscopic surgery has some potential risk factors!!

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Joshi et al. Anesthesiol Clin North America 2001

Risk Factors During LLR Surgery

- **Surgeon related**
  - Difficult surgical technique
  - Fear of oncological inadequacy & tumor spread

  - Recent literature favors laparoscopic vs open surgery!

Canon et al. J Am Coll Surg 2011
Roa et al. Surgeon 2012
Roa et al. Am J Surg 2012

- **Anesthesiologist related:**
  - Prolonged laparoscopic surgery.
  - Risk of gas embolism.
  - Risk of hemorrhage.

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Vigano et al. J Hepatobiliary Pancreat Surg 2009

Prolonged Laparoscopy – Patient Position

- **Long duration of surgery!**
- **Unusual positioning of the patient.**
- **Risk for peripheral nerve damage.**

Joshi et al. Anesthesiol Clin North America 2001

- **Preoperative history & physical assessment**
  - Body habitus & gender
  - Preexcisting neurologic symptoms
    - Alcohol, DM, peripheral vascular disease, arthritis
- **Periodic perioperative assessment of the desired position**

Apfelbaum et al. Anesthesiology 2011

GUIDELINES !!

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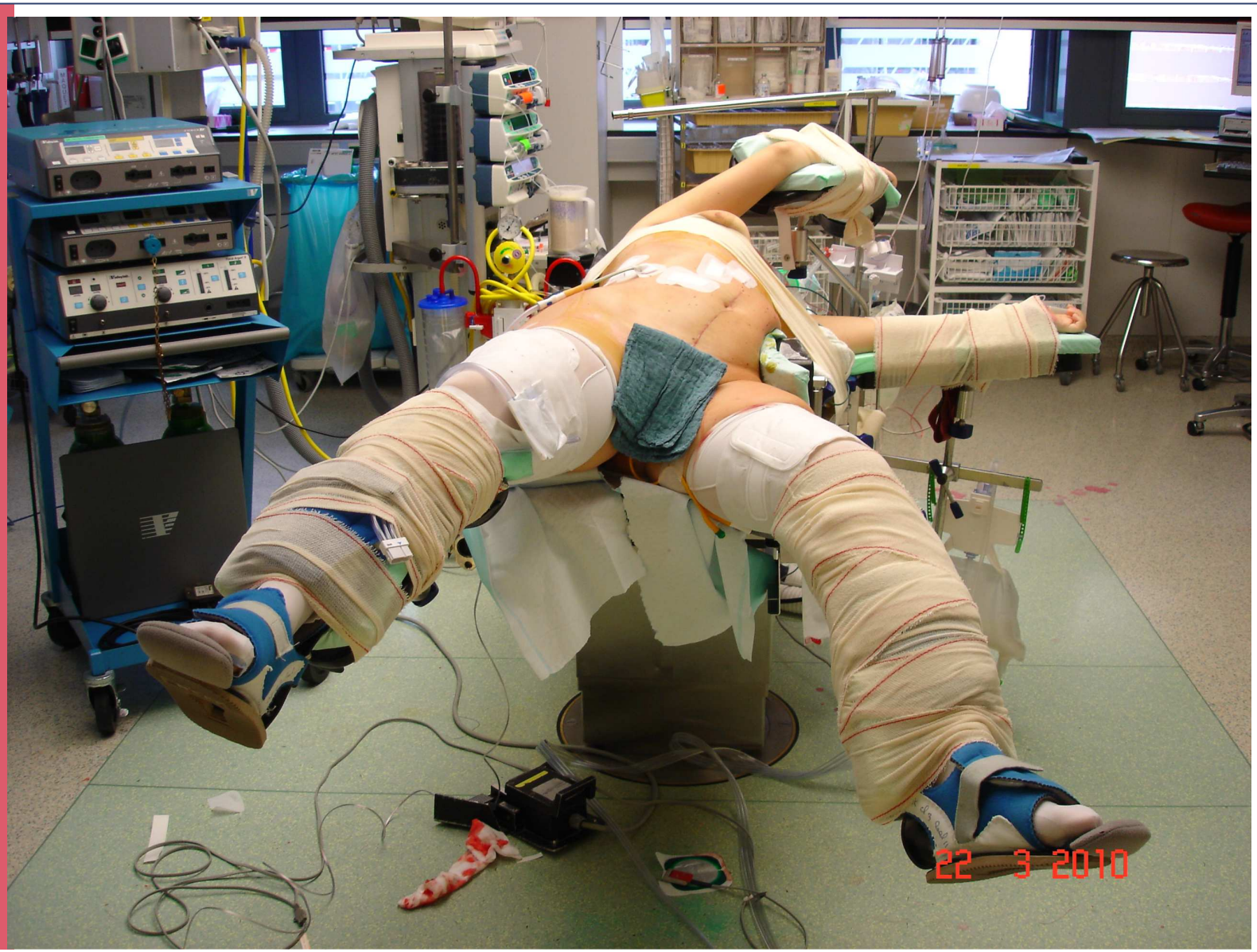
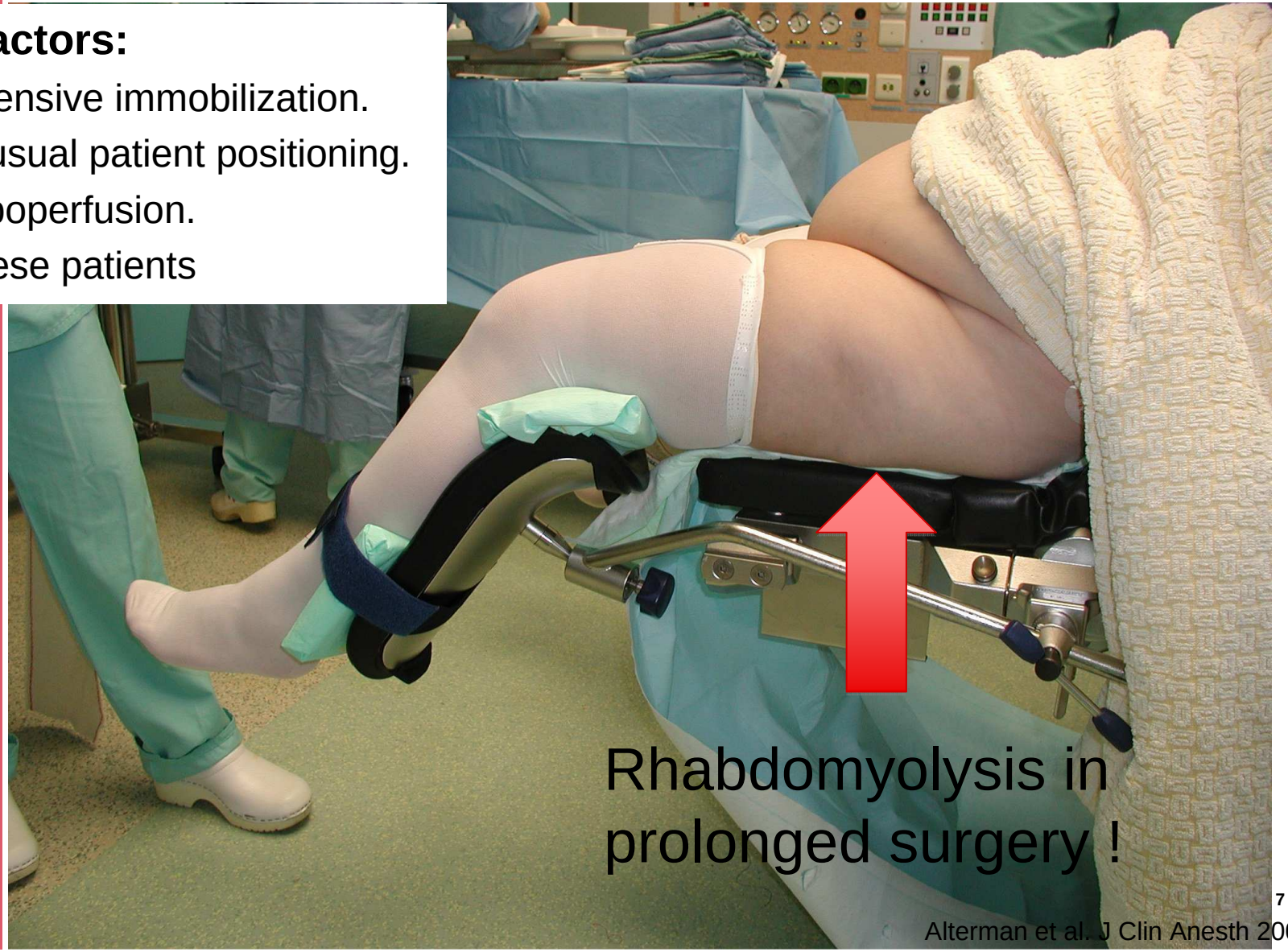

22 3 2010

- **Risk factors:**
  - Extensive immobilization.
  - Unusual patient positioning.
  - Hypoperfusion.
  - Obese patients



Alterman et al. J Clin Anesth 2007

Prolonged Laparoscopy – Rhabdomyolysis

Localized compression of tissue

↓

Pressure in fascial compartement ↑

↓

Bloodflow ↓

↓

Skeletal muscle ischemia → **Rhabdomyolysis**

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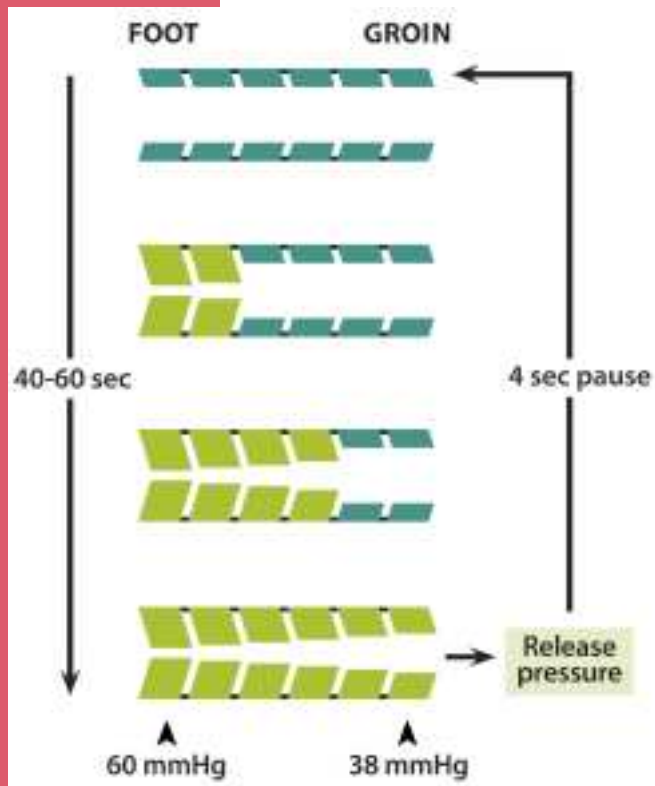
Alterman et al. J Clin Anesth 2007

Prolonged Laparoscopy – IPC

- **Intermittent Pneumatic Compression (IPC)**



Kiefer et al Anesthesiology 2011

- DVT prevention !
  - Laparascopic sugery
  - Abdominal surgery
  - Cancer surgery
  - Patient > 60 year

Muntz et al Am J Surg 2010

- Physiologic Impact !
  - Activation of ISPC resulted…
    - Increased CO
    - Increased SV & EF
    - Increased Preload
    - Reduced Afterload

Bickel et al Am J Surg 2011

Prolonged Laparoscopy – IPC

- **Improved hemodynamic effects!**
  - Reverses adverse hemodynamic effects caused by PPP & head-up tilt position Alishahi et al Ann Surg 2001
  - Pressure equilibration PPP & IPC improved hemodynamics during laparoscopic CCE Bickel et al Arch Surg 2004
- **Improved organ perfusion**
  - Improves hepatic & renal perfusion during PPP Bickel et al Arch Surg 2007
  - Reduces oxidative stress, secondary to relative ischemia-reperfusion insult caused by PPP Bickel et al Ann Surg 2007
  - Restores cerebral oxygen saturation during PPP Kurukahvecioglu et al. Surg Endosc 2008
- **Reduced fluid demands**
  - Reduces fluid demand & improves hemodynamic stability Fiers et al Anesthesiology 2011

Risk For Gas Embolism

- **Definition gas embolism:**
  - Vascular air embolism is the entrainment of air (or exogenously delivered gas) from the operative field or other communication with the environment into the venous or arterial vasculature, producing systemic effects.

- **Incidence unknown!**
- **In many cases, gas embolism occurs subclinical.**
  - Carbon dioxide is highly soluble and rapidly absorbed from the bloodstream!

Yacoub et al. Anesthesiology 1982

Anesthesiologists should be aware for major gas embolism!

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Mirski et al. Anesthesiology 2007

¨ Gas lock ¨

↓

Obstruction of the pulmonary outflow tract

↓

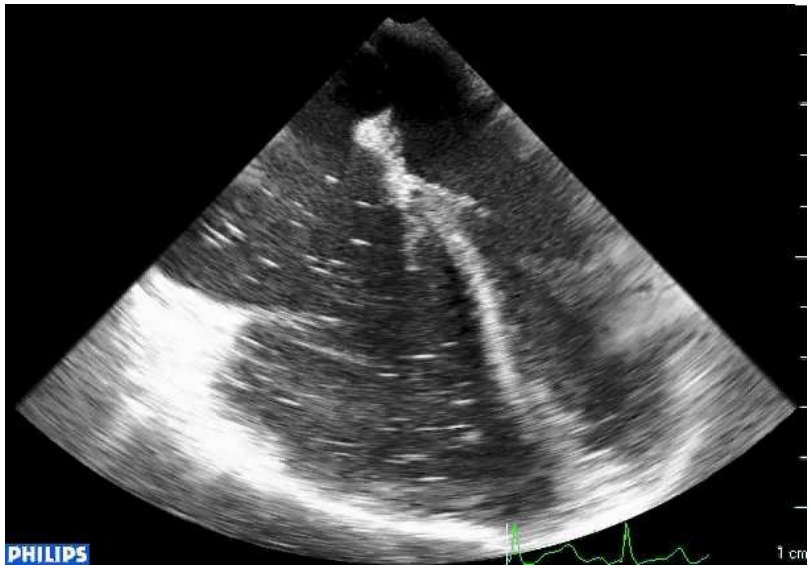
Afterload right ventricle ↑

↓

Acute right heart failure

↓

Cardiac output ↓



Circulatory Collapse

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Mirski et al. Anesthesiology 2007

Risk For Gas Embolism

- **20 – 30% have patent foramen ovale:**
  - Risk of embolism of cerebral and coronary beds.
- **Usually at introduction of pneumoperitoneum.**
  - Verres needle in vein.
  - Laceration of an abdominal vein.
- **Risk gas embolism ≈ insufflation pressure > 15 mmHg**

Bazin et al. Br J Anaesth 1997
Fors et al. Br J Anaesth 2010

Can be delayed.. e.g. portal trapping.

Root et al. Anesth Analg 1978

Mirski et al. Anesthesiology 2007

Risk For Gas Embolism

Laparoscopic liver surgery ➔ high risk gas embolism!

Fors et al. Br J Anaesth 2010

- **Risk factors:**
  - **Lesions of hepatic veins during parenchymal transection.**
  - **Low CVP for prevention of bloodloss.**
  - **Pneumoperitoneum.**
    - Insufflationpressure ± 12 mmHg.
  - **Combination of low CVP and pneumoperitoneum increases the risk of gas embolism!?**
  - **Additional risk if Argon beam coagulator is used.**

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Min et al. Acta Anaesthesiol Scan 2007

Risk For Gas Embolism

- **Argon beam coagulation can give gas embolism**
- **Mechanism ?**
  - Intra-abdominal over-pressurization in combination with open hepatic venous system!
    - Stojeba et al. *Acta Anaesthesiol Scand* 1999
    - Kono et al. *Br J Anaesth* 2001
    - Adachi et al. *Anesth Analg* 2006
    - Min et al. *Acta Anaesthesiol Scand* 2007
    - Ikegami et al. *J Hepatobiliary Pancreat Surg* 2009
- **Cavitron Ultrasonic Surgical Aspirator (CUSA)**
  - ↑ risk gas embolism!!!
    - Koo et al. *Anesth Analg* 2005
    - Lee et al. *Korean J Anesthesiol* 2010

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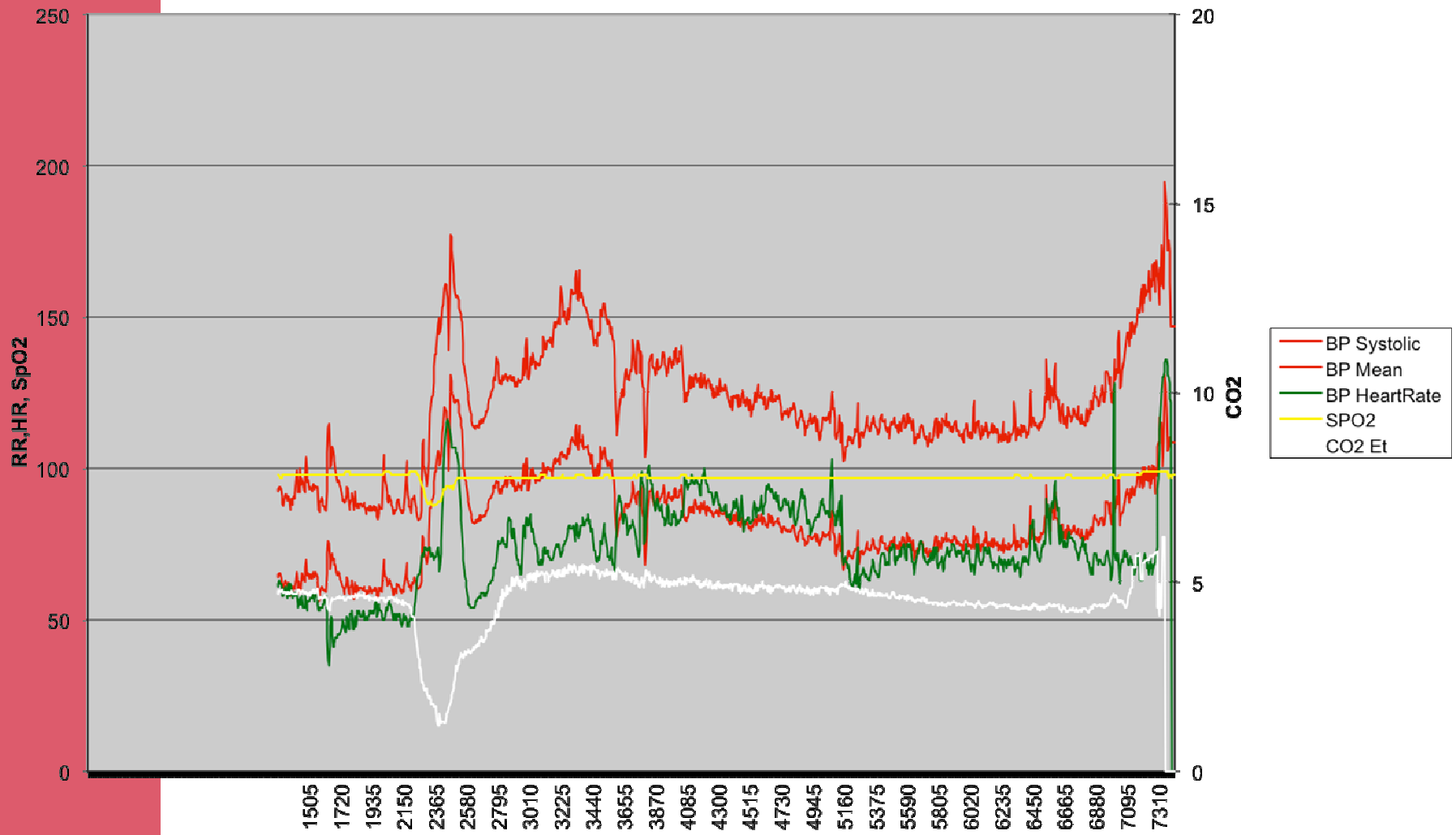

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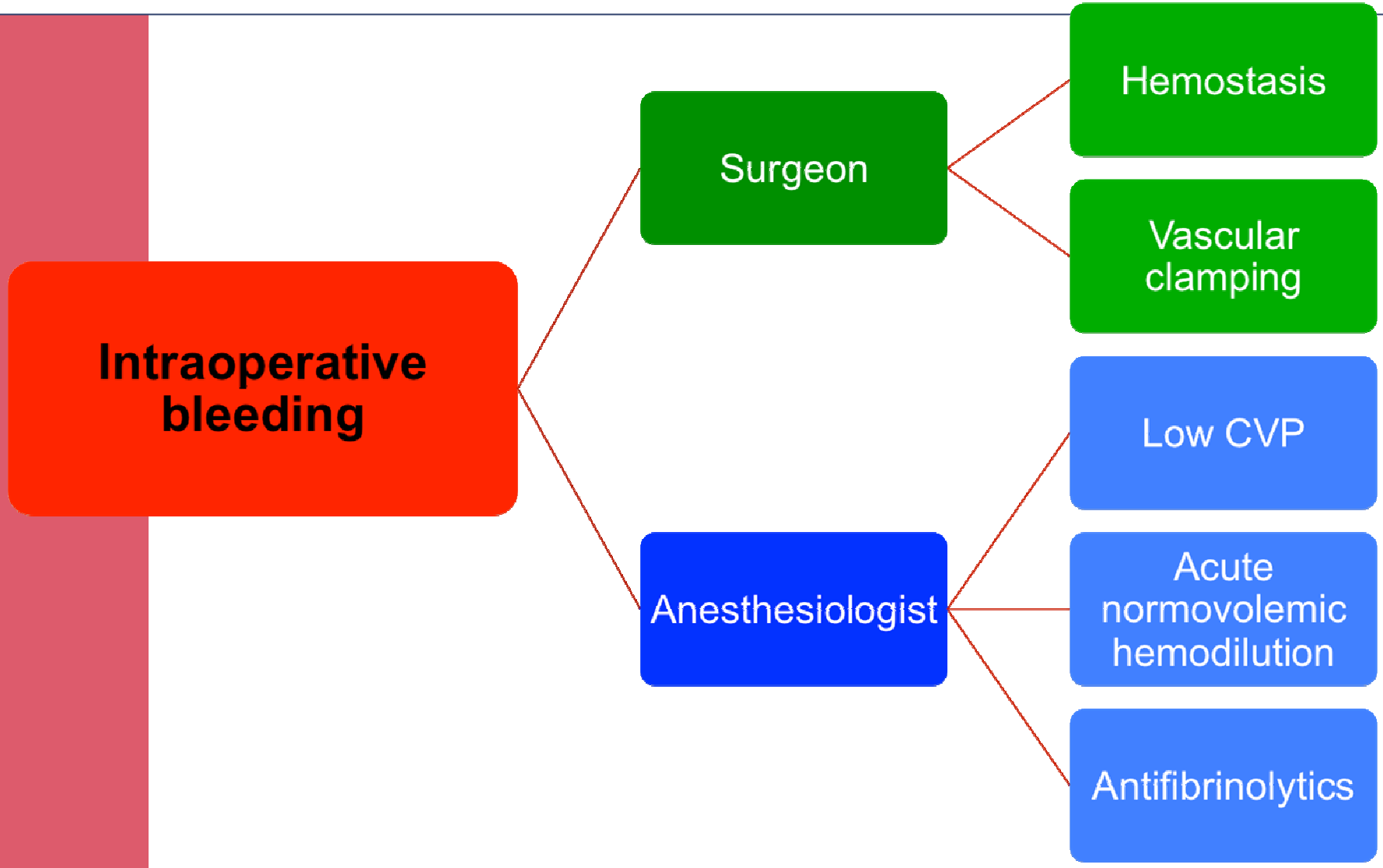
Management

Risk For Gas Embolism

- **Prevention of futher gas entry & reduce volume of gas!**
  - Notify the surgeon – Stop insufflation & release pneumoperitoneum
- **Treatment management**
  - 100% oxygen
  - Hyperventilation & PEEP
  - Reduce embolic obstruction **Relieve ¨ gas lock ¨**
    - Durant maneuver (left lateral decubitus)
    - Trendelenburg position
  - Hemodynamic support
    - Vasopressor (dobutamine & noradrenaline), fluid & CPR
  - Aspiration of gas from right atrium
    - Central venous catheter or pulmonary artery catheter
    - Low succes rate 6 – 16% !!

Mirski et al. Anesthesiology 2007



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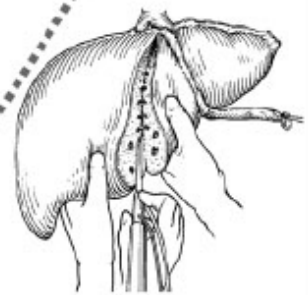
Stage 1	Stage 2	Stage 3
Dissection	**Transsection of parenchyma**	**Check of resection surface**
- Identification efferent and afferent vessels - Relative minor blood loss	Blood loss related to: - Surgical technique - Dissection Device - Quality of the liver - Central venous pressure	- Hemostasis - Biliostasis - Application of topical hemostatic agent
Amount of Blood Loss		**Closure**

Stellingwerf et al. Semin Thromb Hemost 2012

Anesthesiological Management?

Haemodynamics

- Low CVP
  - Vasodilators
  - Forced diuresis
- Intraoperative fluid status
  - Fluid restriction
  - Acute normovolemic haemodilution
  - Phlebotomy

Gold standard?

Pharmalogical interventions

- Topical Hemostatic agents
- Antifibrinolytics
- Procoagulant drugs

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Stellingwerf et al. Semin Thromb Hemost 2012

Intraoperative bleeding & low CVP

TABLE III. Summary of Important Prospective Randomized Studies Evaluating Physiologic Variable Manipulation in Hepatectomy Procedures

Author	Year	N	Method(s) tested	Control	Blood loss	Complications
Zhu	2012	192	Low CVP, IVC clamp-induced	Low CVP, anesthetic-induced	Decreased	No difference
Rahbari	2011	128	Low CVP, IVC clamp-induced	Low CVP, anesthetic-induced	Decreased	No difference (decreased pulmonary emboli)
Kato	2008	85	Low CVP, IVC clamp-induced	Uncontrolled CVP	No difference	No difference
Jamagin	2008	130	Acute Normovolemic Hemodilution	Allogenic transfusion	No difference	No difference (decreased allogenic transfusion)
Wang	2006	50	Low CVP, anesthetic-induced	Uncontrolled CVP	Decreased	No difference
Hasegawa	2002	80	Low CVP, hypoventilation-induced	Uncontrolled CVP	No difference	No difference
Matot	2002	78	Acute Normovolemic Hemodilution	Allogenic transfusion	No difference	No difference (decreased allogenic transfusion)

- **Low CVP**
  - CVP less then 5 mmHg
  - Decreases intraoperative blood loss & transfusion requirements.
    - Both for major & minor hepatectomy!
  - Risk for gas embolism & hypoperfusion.
  - Mechanism:
    - Fluid restriction.
    - Pharmacological.

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Huntington et al. J Surg Oncol 2014

Intraoperative bleeding & low CVP

Volume of blood loss during liver resection correlates with the central venous pressure (CVP). (n = 100)

Reducing CVP to less then 5 cmH_2O ($\pm$ 3 mmHg) is a simple and effective way to reduce blood loss during liver surgery.

Johnson et al.	*Br J Surg* 1998	(n = 20)
Jones et al.	*Br J Surg* 1998	(n = 100)
Bui et al.	*HPB* 2002	(n = 151)
Smyrniotis et al.	*Am J Surg* 2004	(n = 102)
Wang et al.	*World J Gastroenterol* 2006	(n = 100)

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Intraoperative bleeding & low CVP

- **CVP during hepatic resection is not associated with intraoperative blood loss**
  - Kim et al *Acta Anaesthesiol Scan* (n = 964)
  - Chhiber et al *Liver Transpl* 2007 (n = 100)
  - Lutz et al *Anesth & Analg* 2003 (n= 44)

- **Low CVP ≠ restrictive fluid management!**
  - Poor relationship CVP & blood volume / fluid responsiveness
  - Volume to maintain preload & cardiac index Marik et al. Chest 2008
    - Open surgery 5,9 ± 2 ml/kg/h
    - Laparoscopic surgery 3,4 ± 0,8 ml/kg/h Concha et al. Anest Analg 2009

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Intraoperative bleeding & low CVP

- **Pneumoperitoneum & CVP**
  - CVP_{tm} = transmural pressure (distending pressure) ***preload***
    - Influenced by pressure inside the vessel (CVP)
    - Influenced by surrouding pressure = pleural pressure (P_{pl})

$$\mathbf{CVP = CVP_{tm} + P_{pl}}$$

Valenza et al. Best Pract Res Clin Anaesthesio 2010

- **Association between CVP – PPP – gas embolism**
  - Gas embolism occurs frequently during LLR.
  - Clinically, this finding appaers to be normal !
  - Risk gas embolism ↑ with dissection around large veins.

Jayaraman et al. Surg Endosc 2010

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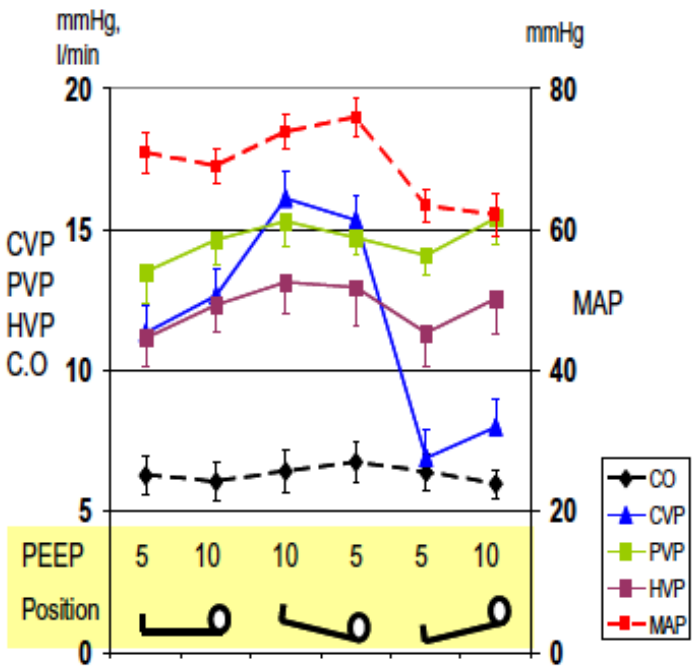
Intraoperative bleeding & low CVP

- **Association between patient position & PEEP on CVP – HVP – PVP**
  - Changes in body position affects CVP but not HVP & PVP.
  - Increasing PEEP has only a small effect on CVP – HVP – PVP.



Changing body position is not effective in reducing venous pressure in the liver!

Sand et al. Acta Anaesthesiol Scan 2011

Intraoperative Bleeding & ANH

- **Goal:**
  - Preoperative dilution of circulating blood volume in order to reduce the amount of red blood cells & plasma lost during surgical bleeding!
- **Basic principles**
  - Withdraw blood before major surgical bleeding!
  - Maintain normovolemia (cristalloid / colloid)
  - Target Hct 25 – 30%
  - 10 – 15 min per bag of 450ml
  - Estimated Blood Volume
    - $(Hct_{start} – Hct_{goal} / Hct_{start} + Hct_{goal})/2 \times TBV$
    - Estimated bloodloss = $\pm$ 25 – 30% of TBV
- **Contra-indications for AHN**
  - Ischemic heart disease.
  - Cerebrovascular disease.

Jamnicki et al. J Cardiothorac Vasc Anesth 2003

Matching oxygen delivery & oxygen demand

Intraoperative Bleeding & ANH

- **Cardiovascular physiology during ANH**
  - Oxygen content ↓
    - $CaO_2 = (Hb \times 1{,}34 \times SaO_2) + (PaO_2 \times 0{,}003)$ ± 20 ml/dl blood
  - Maintain oxygen consumption by ↑ cardiac output & ↑ OER
    - $VO_2 = CO \times (CaO_2 - CvO_2)$ ± 250 ml/min
    - Lower mixed venous oxygen saturation
    - Regional bloodflow redistribution & microvascular adjustment
    - VO_2 independt of delivery! OER ± 25%
  - Maintain oxygen delivery by ↑ cardiac output
    - $DO_2 = CaO_2 \times CO$ ± 1000 ml/min

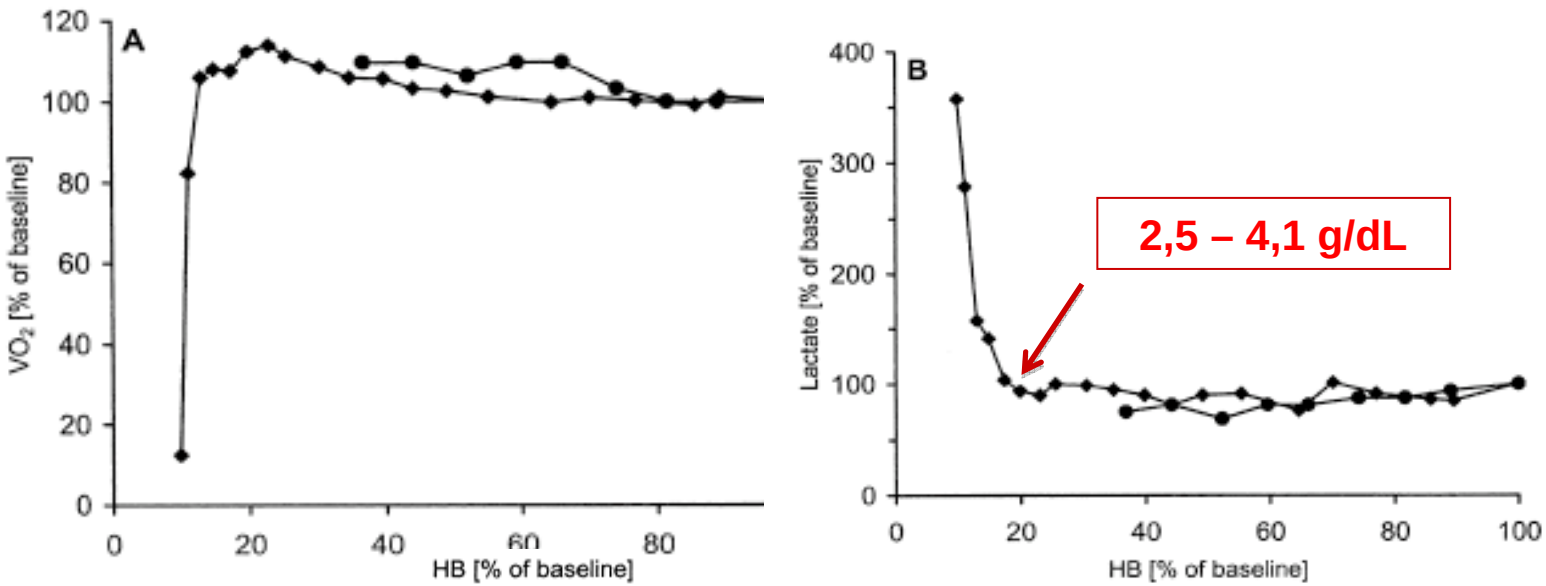
- **Effect anesthesia:**
  - Depression of autonomic nervous system
  - CO ↑ due to SV ↑ (no HR ↑)

Jamnicki et al. J Cardiothorac Vasc Anesth 2003

Intraoperative Bleeding & ANH

- **Critical hemoglobin**
  - VO_2 supply-dependent! (compensatory mechanism depleted)
  - $VO_2 \approx DO_2$ **Lactate ↑**

Critical DO_2 = 10 ml O_2/kg/min



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Jamnicki et al. J Cardiothorac Vasc Anesth 2003

Intraoperative Bleeding & ANH

- **Acute Normovolemic Haemodilution in Liver surgery**
  - ANH reduces allogeneic blood transfusion!
  - ANH results in higher postoperative HgB levels
  - ANH > 800 ml reduction of allogeneic blood & plasma transfusion!
    - Matot et al. *Anesthesiology* 2002 (n = 78)
    - Jarnagin et al. *Ann Surg* 2008 (n = 113)
    - Balci et al. *Transplant Proceed* 2008 (n = 114)

- **ANH is safe & effectively reduces the need for allogeneic transfusions during liver surgery!**

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Intraoperative Bleeding & Antifibrinolytics

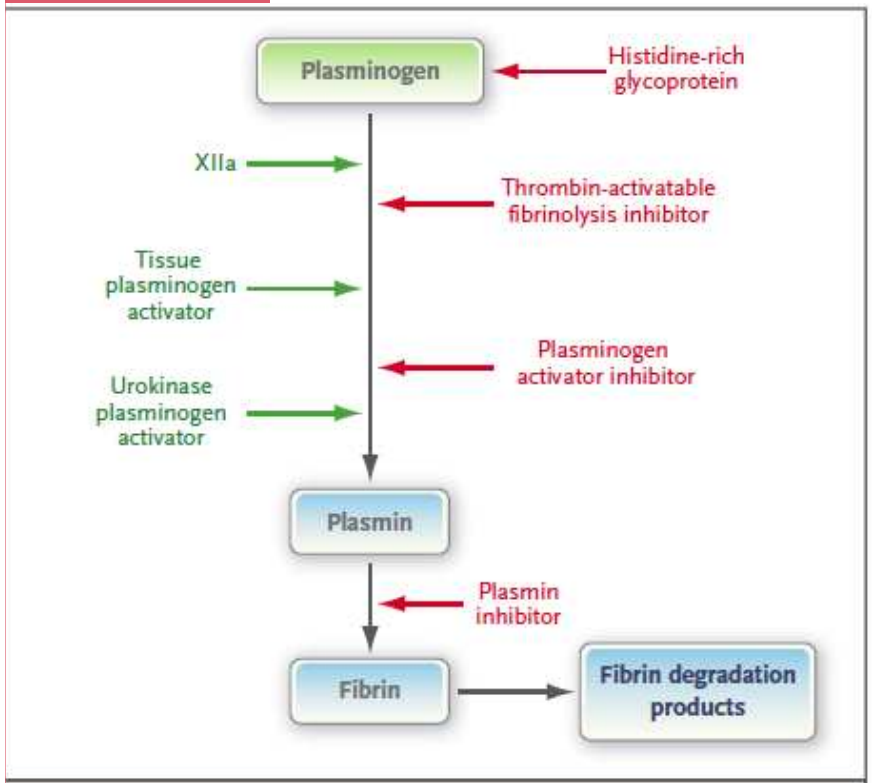

Figure 3. Fibrinolysis Activation and Inhibition.
Green and red arrows represent activators and antiactivators, respectively. XIIa denotes activated factor XII.

- **Antifibrinolytic Agents**
  - Lysin analogs:
    - Inhibiton plasminogen-plasmin conversion.
      - Tranexamic acid (TXA).
      - Epsilon-aminocaproic acid.
  - Serine protease inhibitors:
    - Inhibition plasmin.
      - Aprotinin.
      - Nafamostat mesilate.

- BART trial 2008 *NEJM*
- CRASH-2 trial 2011 *Lancet*
- MATTERs study 2012 *Arch Surg*

Goodnough et al. Anest Analg 2013

Intraoperative Bleeding & Antifibrinolytics

Could antifibrinolytic agents reduce bloodloss during liver resection?

Aprotinin and **tranexamic acid** show promise in reduction of blood transfusion requirements in liver resections!

Cheng-Chung Wu et al. *Ann Surg* 2006 (n = 214)

Routine use ? TEG – ROTEM guided ?
Further research is needed!

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Gurusamy et al. Cochrane Review 2009

Intraoperative Bleeding & EBM ???

- **Cardiopulmonary interventions to decrease blood loss and blood transfusion requirements for liver resection**
  - Meta-analysis!
    - 10 trials – 617 patients.
      - High risk of bias!
      - High risk of ¨ random error ¨ .
    - Cardiopulmonary interventions
      - Low CVP
      - **Haemodilution**
      - **Haemodilution with hypotension**
      - Hypoventilation
  - **Further research needs to be done!**

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Gurusamy et al. Cochrane Review 2012

Laparoscopic Liver Surgery & ERAS

Preoperative
Preoperative counseling
Minimal preoperative fasting (solid food up to 6 h + clear fluids up to 2 h) + carbohydrate loading
No anxiolytic premedication
Perioperative
Thoracic epidural analgesia
Prevention of hypothermia
CVP monitoring (CVP <5 mmHg)
No routine drainage of the peritoneal cavity
No standard nasogastric drainage
Start intake of water and free fluids
Early mobilization
Postoperative nausea and vomiting (PONV) prophylaxis
Antithrombotic prophylaxis
Antibiotic prophylaxis
Postoperative days 1–3
Daily review of discharge criteria
Ileus prevention (MgO/Macrogol/Lactulose)
Free fluids/normal diet POD 1
Intravenous fluids discontinued POD 1
Oral analgesia POD 1
Normal diet POD 2
Removal of urinary catheter POD 2
Stop epidural/intravenous analgesia POD 3
Full mobilization POD 3

- **Perioperative care varied considerably among centers!**
- **Most centers have some elements of the ERAS program.**
- **Anesthetic aspects of ERAS program in UZ Ghent not yet implied!**
- **Future prospective?????**

Wong-Lun-Hing et al. World J Surg 2014

Conclusion

- **Indications for LLR are growing with good results**
- **LLR has specific problems for both surgeons & anesthesiologist**
- **Gas embolism occurs frequently, are usually subclincial however anesthesiologist should be aware of the risk!**
- **Intraoperative bleeding requires good communication between surgeons & anesthesiologist! ANH & intraoperative controlled hypotension can be used to reduced perioperative bloodloss..**

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