Anesthetic Management During Minimal Invasive Liver Surgery

Jurgen van Limmen, M.D.
Department of Anesthesiology
University Hospital Ghent,
Belgium

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Anesthetic Considerations

Surgical Considerations
Risk Factors During Laparoscopic Surgery

- Pneumoperitoneum.
- 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!!
Risk Factors During LLR Surgery

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

- Recent literature favors laparoscopic vs open surgery!

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

Roa et al. Surgeon 2012

Prolonged Laparoscopy – Patient Position

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


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

Apfelbaum et al. Anesthesiology 2011

GUIDELINES !!
Rhabdomyolysis in prolonged surgery!

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

Prolonged Laparoscopy – Rhabdomyolysis

Localized compression of tissue

Pressure in fascial compartment ↑

Bloodflow ↓

Skeletal muscle ischemia → Rhabdomyolysis

Prolonged Laparoscopy – IPC

Intermittent Pneumatic Compression (IPC)

- DVT prevention!
  - Laparoscopic surgery
  - Abdominal surgery
  - Cancer surgery
  - Patient > 60 year

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

Kiefer et al Anesthesiology 2011

Muntz et al Am J Surg 2010

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  
  - 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!

**Anesthesiologists should be aware for major gas embolism!**

Yacoub et al. Anesthesiology 1982

Mirski et al. Anesthesiology 2007
"Gas lock"

Obstruction of the pulmonary outflow tract

Afterload right ventricle \( \uparrow \)

Acute right heart failure

Cardiac output \( \downarrow \)

Circulatory Collapse
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**

Fors et al. Br J Anaesth 2010

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


Mirski et al. Anesthesiology 2007
Risk For Gas Embolism

Laparoscopic liver surgery ➔ high risk gas embolism!

Risk factors:

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

Fors et al. Br J Anaesth 2010
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!
    - Ikekami 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
Risk For Gas Embolism

- Prevention of further 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 success rate 6 – 16% !!
Intraoperative bleeding

Surgeon

Hemostasis

Vascular clamping

Low CVP

Acute normovolemic hemodilution

Antifibrinolytics
<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dissection</strong></td>
<td><strong>Transsection of parenchyma</strong></td>
<td><strong>Check of resection surface</strong></td>
</tr>
</tbody>
</table>
| - Identification efferent and afferent vessels | - 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

Pharmacological interventions

- Topical Hemostatic agents
- Antifibrinolytics
- Procoagulant drugs

Gold standard?
Intraoperative bleeding & low CVP

- **Low CVP**
  - CVP less than 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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TABLE III. Summary of Important Prospective Randomized Studies Evaluating Physiologic Variable Manipulation in Hepatectomy Procedures

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

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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 cmH₂O (± 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)
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
    - Open surgery: $5.9 \pm 2\, \text{ml/kg/h}$
    - Laparoscopic surgery: $3.4 \pm 0.8\, \text{ml/kg/h}$

  Marik et al. *Chest* 2008

Concha et al. *Anest Analg* 2009
Intraoperative bleeding & low CVP

**Pneumoperitoneum & CVP**

- CVP<sub>tm</sub> = transmural pressure (distending pressure)  
  - Influenced by pressure inside the vessel (CVP) 
  - Influenced by surrounding pressure = pleural pressure (P<sub>pl</sub>)

\[
\text{CVP} = \text{CVP}_{\text{tm}} + P_{\text{pl}}
\]

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
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
  - \((Hct_{\text{start}} - Hct_{\text{goal}} / Hct_{\text{start}} + Hct_{\text{goal}})/2 \times TBV\)
  - Estimated bloodloss = ± 25 – 30% of TBV

Contra-indications for AHN
- Ischemic heart disease.
- Cerebrovascular disease.

Intraoperative Bleeding & ANH

- Cardiovascular physiology during ANH
  - Oxygen content ↓
    - \( \text{CaO}_2 = (\text{Hb} \times 1.34 \times \text{SaO}_2) + (\text{PaO}_2 \times 0.003) \) ± 20 ml/dl blood
  - Maintain oxygen consumption by ↑ cardiac output & ↑ OER
    - \( \text{VO}_2 = \text{CO} \times (\text{CaO}_2 - \text{CvO}_2) \) ± 250 ml/min
  - Lower mixed venous oxygen saturation
  - Regional bloodflow redistribution & microvascular adjustment
  - \( \text{VO}_2 \) independent of delivery! OER ± 25%
  - Maintain oxygen delivery by ↑ cardiac output
    - \( \text{DO}_2 = \text{CaO}_2 \times \text{CO} \) ± 1000 ml/min

- Effect anesthesia:
  - Depression of autonomic nervous system
  - \( \text{CO} \uparrow \) due to \( \text{SV} \uparrow \) (no HR ↑)

Intraoperative Bleeding & ANH

- Critical hemoglobin
  - VO₂ supply-dependent!
  - VO₂ ≈ DO₂ (compensatory mechanism depleted)
- Lactate ↑

Critical DO₂ = 10 ml O₂/kg/min

2,5 – 4,1 g/dL

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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)
- Balci et al. Transplant Proceed 2008 (n = 114)

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

**Antifibrinolytic Agents**

- **Lysin analogs:**
  - Inhibition 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!
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!
Laparoscopic Liver Surgery & ERAS

- 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??????

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.