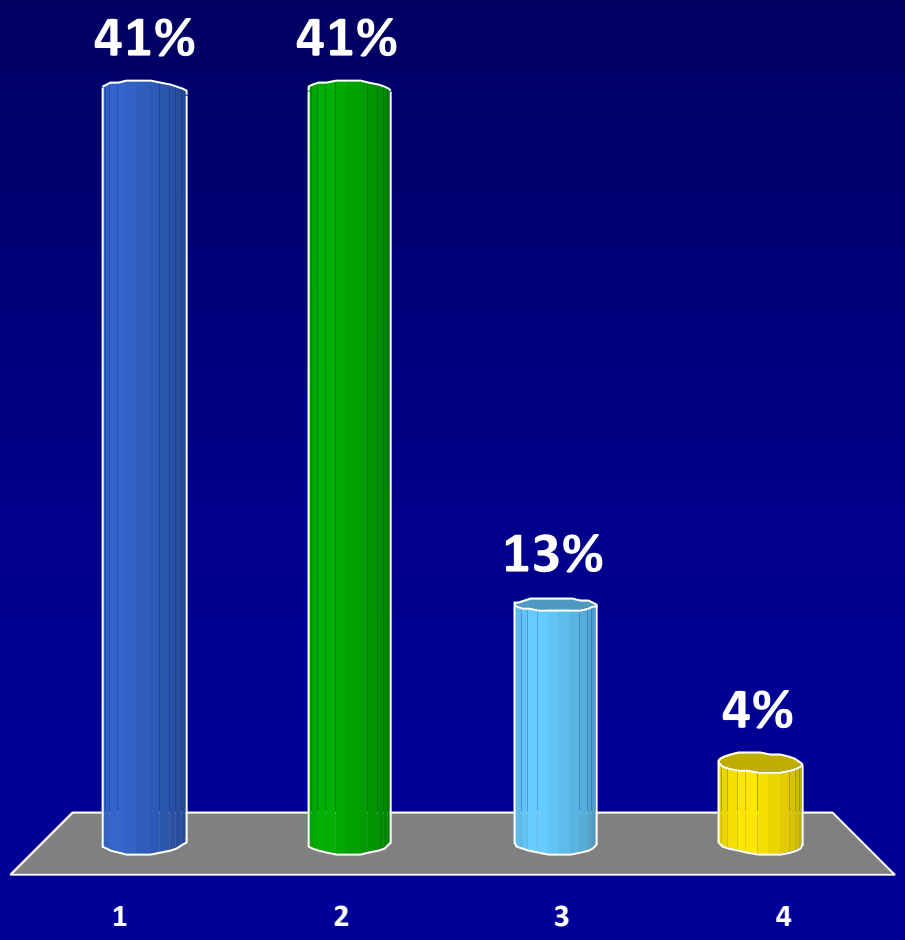
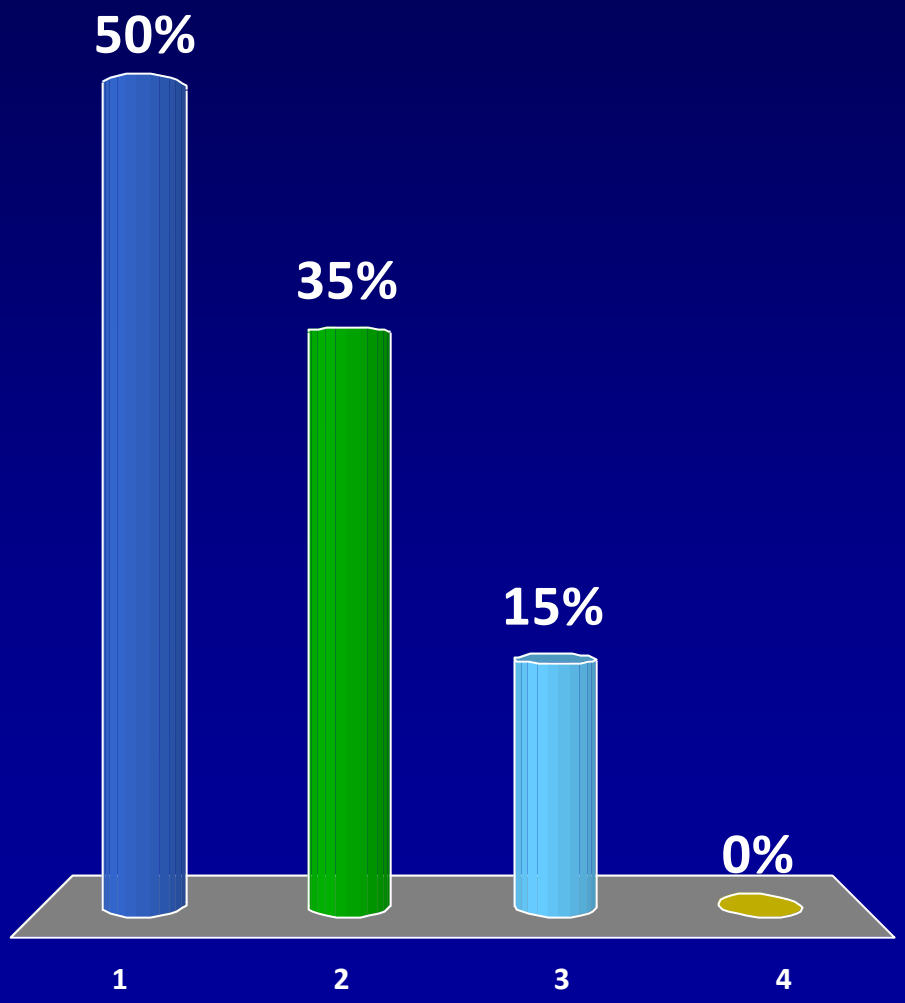
Question 1: What percentage of the total US volume of liver transplants are split liver grafts?

1. < 5%
2. 5%-10%
3. 10%-15%
4. 15%- 20%



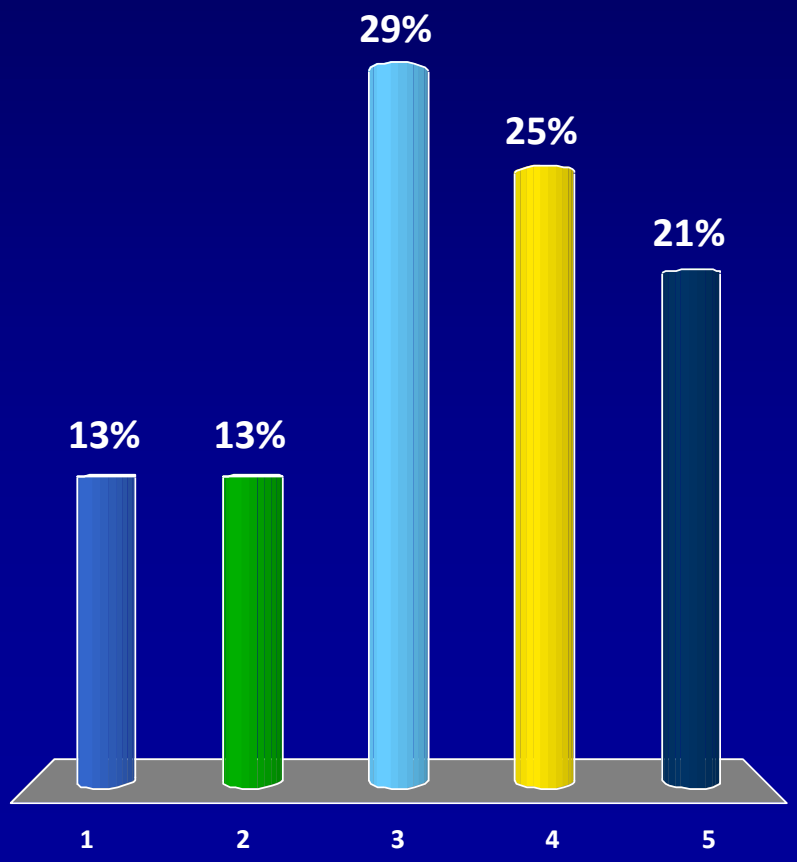
Question 2: What percentage of the total US volume of liver transplants are living donor liver grafts?

1. < 5%
2. 5%-10%
3. 10%-15%
4. 15%- 20%

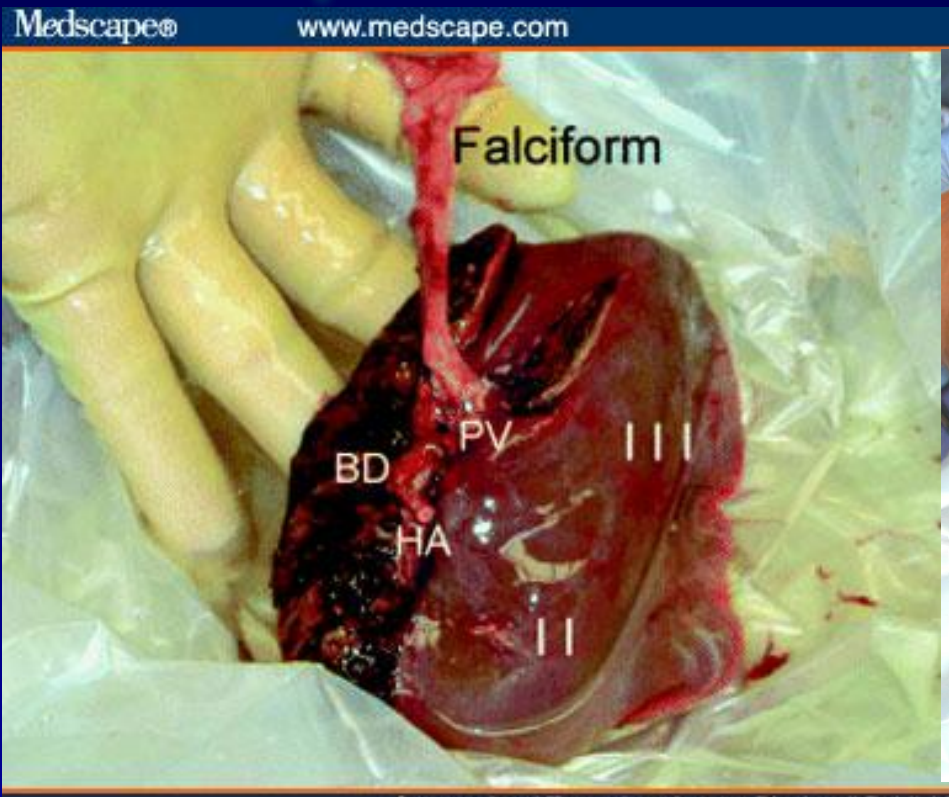


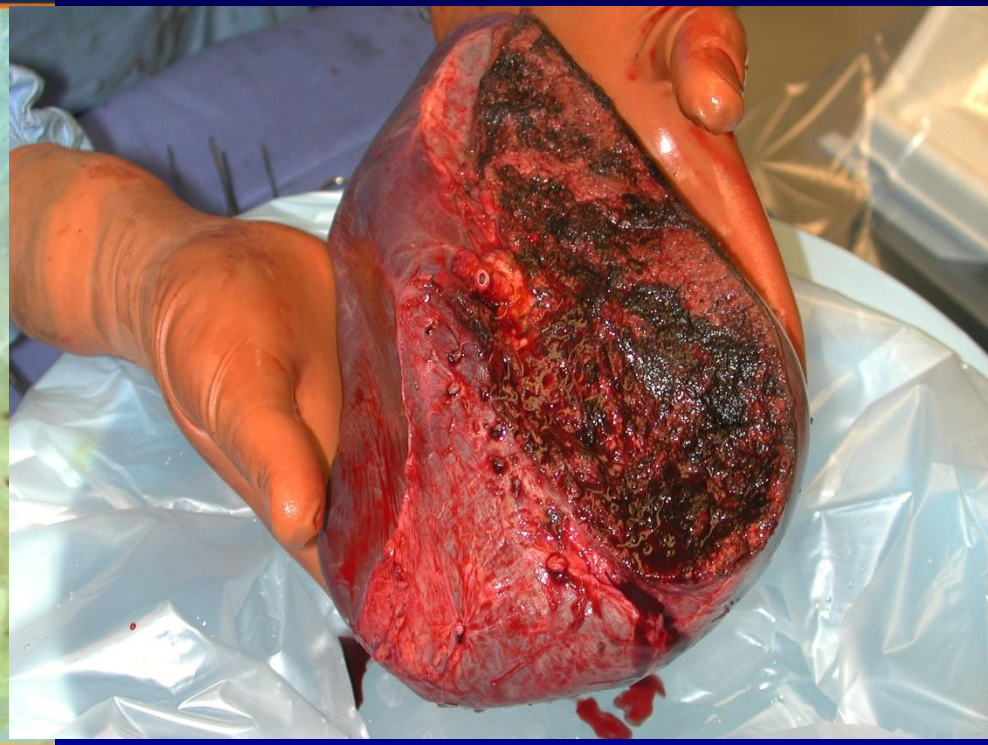
The minimum number of adult LDLT procedures needed to be performed in order to overcome the "learning curve" (below which is associated with a statistically higher incidence of graft failure) is?

1. 10
2. 15
3. 20
4. 25
5. 40



Split and Partial Liver Grafts: Technical Aspects and Program Preparation

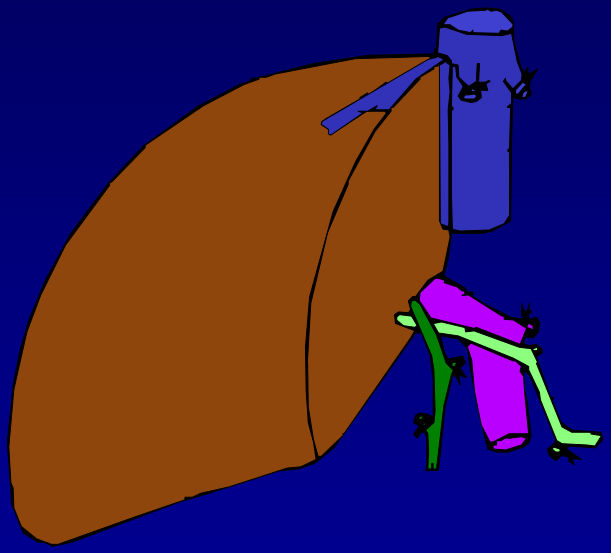




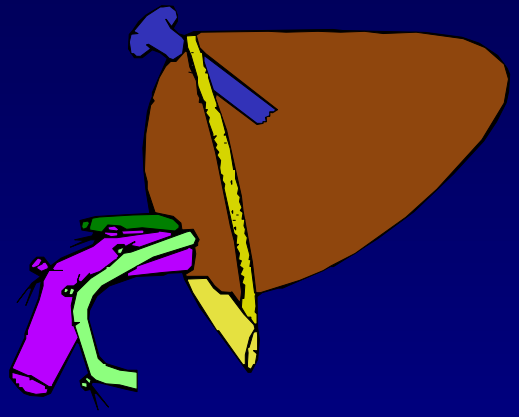
Elizabeth A. Pomfret, M.D., Ph.D.
Professor of Surgery, Tufts University, Boston, MA
Chair, Department of Transplantation and Hepatobiliary Diseases
Lahey Clinic Medical Center

1. Anatomy and Definitions
2. Split Liver Transplants
   - Classic vs. Left/Right Split
   - Ex situ vs. in situ
   - Surgical Techniques/Team Resources
3. Living Donor Liver Transplants
   - Adult vs. Pediatric
   - Donor Selection and Preoperative Evaluation
   - Surgical Techniques/Team Resources

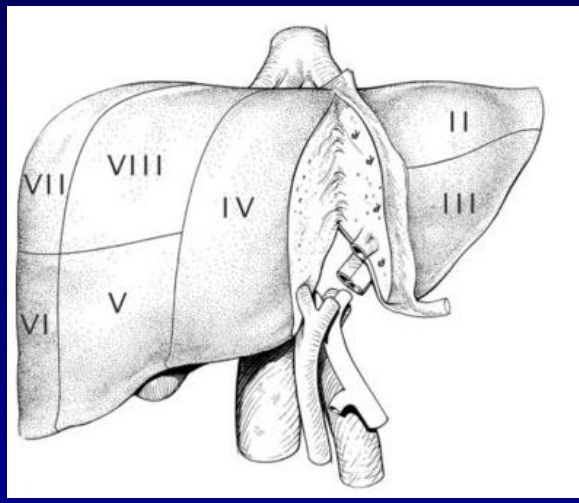
Split Liver Transplantation is in a Deceased Donor Graft

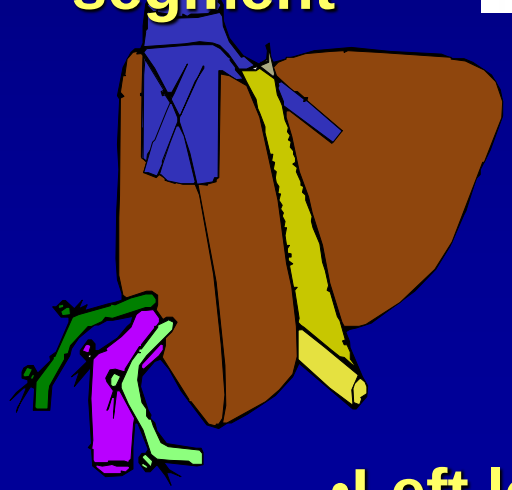


•Right lobe ± medial segment left



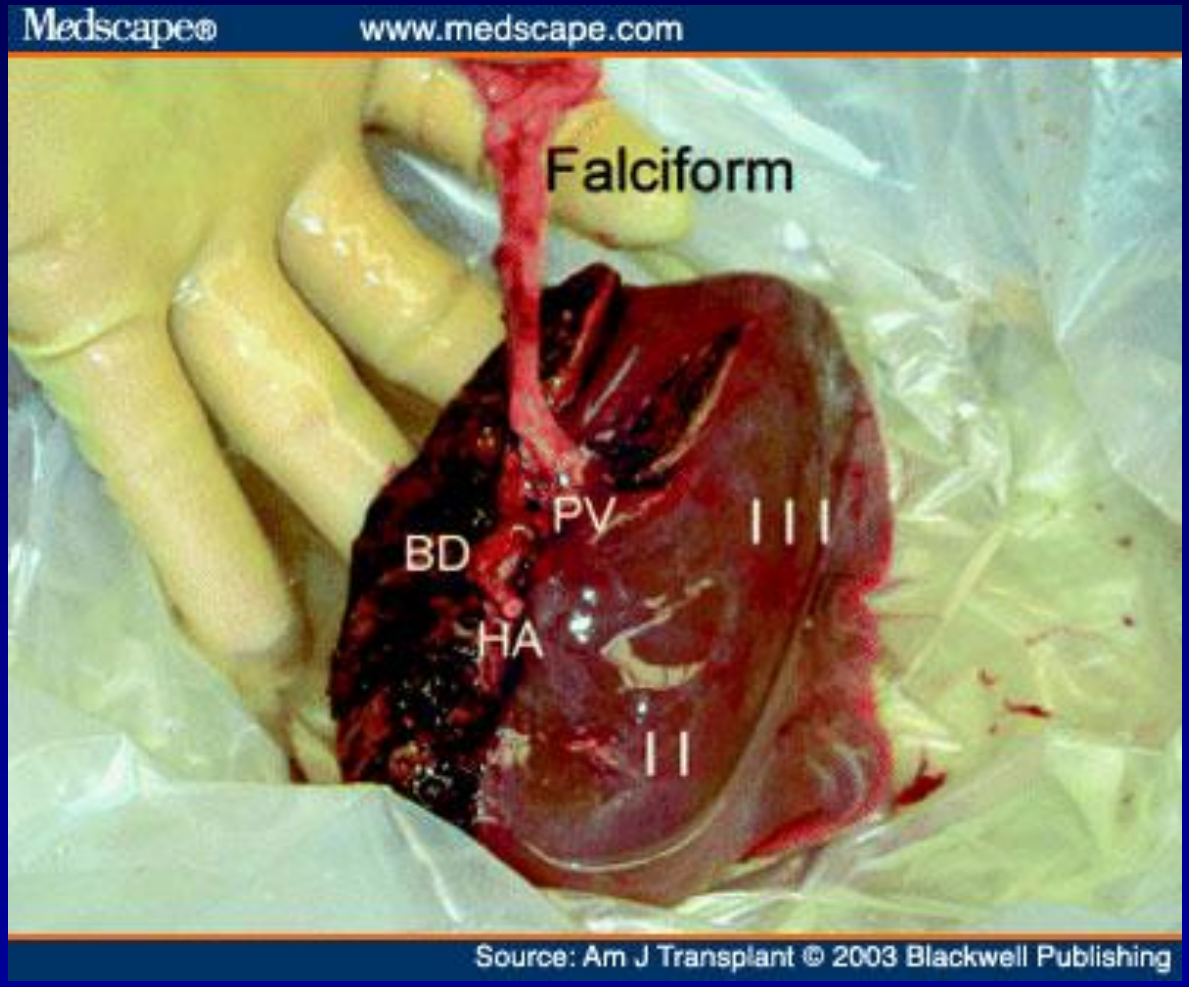
•Left lateral segment





•Left lobe

“Classic Split”: LLS graft for a Pediatric Patient



“Two Sides of a Split”

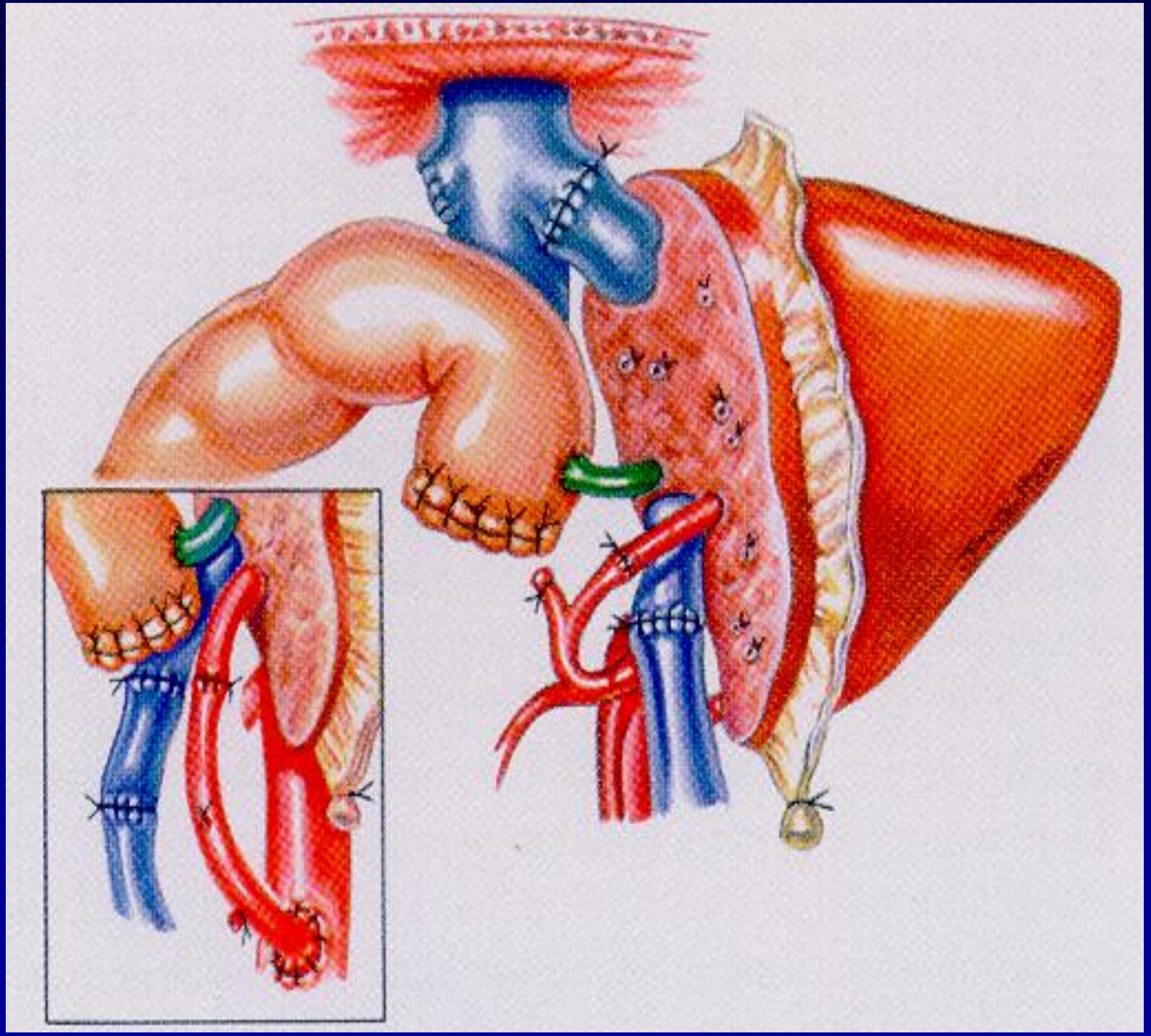
Picture provided by Kim Olthoff MD

Split Liver Transplantation

Issues

- In situ vs. ex situ splitting
- Operative time for other organ teams
- Determining proper recipient of right lobe
- Informed consent for right lobe recipient
- Anatomic variations
- Radiologic assessment for hemi-hepatectomy

  (2 adult recipients)



Long-term Outcomes for Whole and Segmental Liver Grafts in Adult and Pediatric Liver Transplant Recipients: A 10-Year Comparative Analysis of 2,988 Cases

Journal of the American College of Surgeons - Volume 208, Issue 5 (May 2009) -

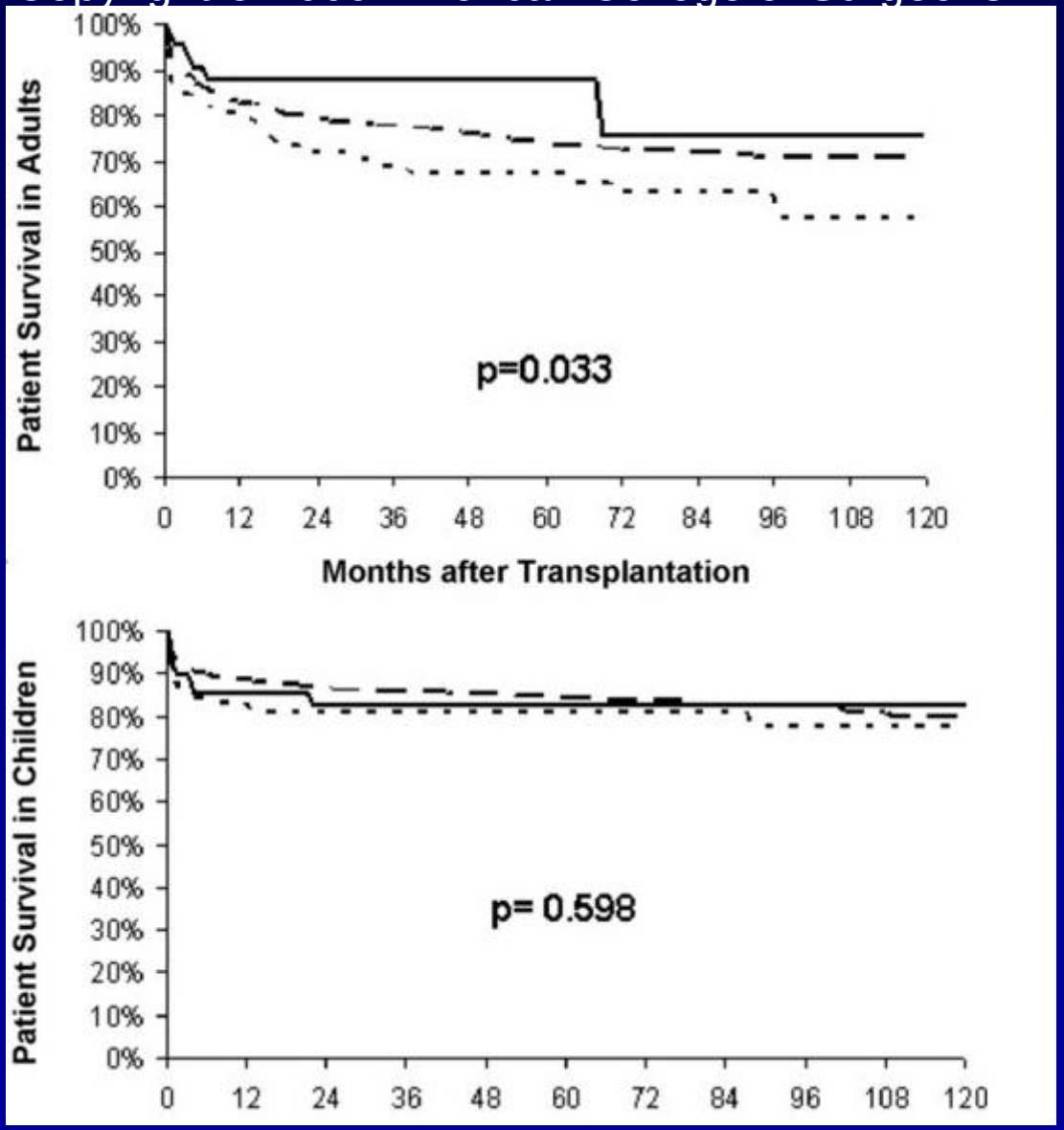


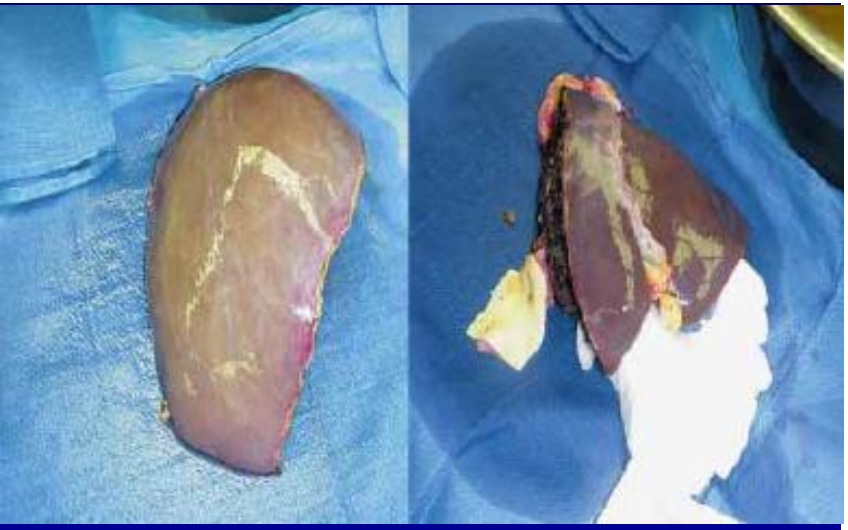
Figure 3 Patient survival after liver transplantation. (A) Adult. Solid line, living-donor right liver graft; dashed line, whole liver; dotted line, split extended right liver graft. (B) Children. Solid line, living-donor left lateral liver graft; dashed line, whole liver; dotted line, split-graft left-lateral liver transplantation.

American Journal of Transplantation 2001; 1: 366–372
Munksgaard International Publishers

ISSN 1600-6135

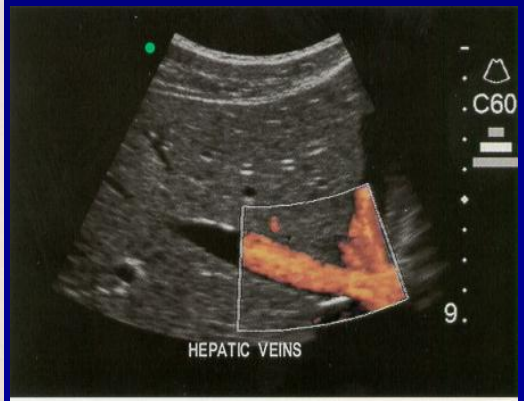
Split Liver Transplantation for Two Adult Recipients: An Initial Experience

Abhinav Humar*, Thiagarajan Ramcharan, Timothy D. Sielaff, Raja Kandaswamy, Rainer W. Gruessner, John R. Lake and William D. Payne



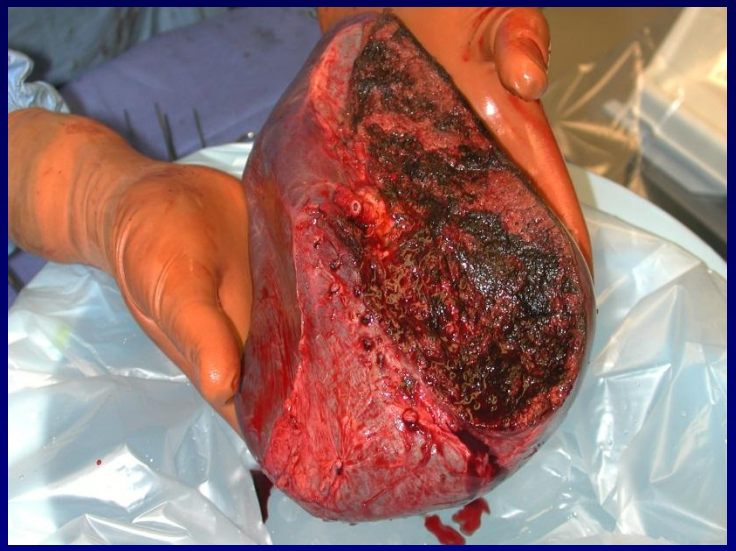
We split livers from 6 cadaver donors, and transplanted 12 adult recipients. All splits were performed *in situ* with transection through the midplane of the liver, resulting in a right lobe and a left lobe graft. Mean donor age was 19.7 years; mean donor weight was 79.1 kg. Mean recipient age was 41.5 years. Mean weight of right lobe recipients was 89 kg; left lobe recipients, 60 kg. All donors were hemodynamically stable and had normal liver function tests. Mean operative time for the procurement was 7.4 h. Average blood loss during the transection of the liver was 490 mL. Mean GW/RW ratio for all recipients was 0.87%; right lobe recipients, 0.86%; and left lobe recipients, 0.88%. With mean follow-up of 9.3 months, patient and graft survival rates were both 83.3%. There were 2 deaths: 1 after hepatic artery thrombosis (HAT) and subsequent multiorgan failure; the other after HAT, a liver retransplant, and subsequent gram-negative sepsis. The remaining 10 recipients are doing well. We observed no cases of primary nonfunction

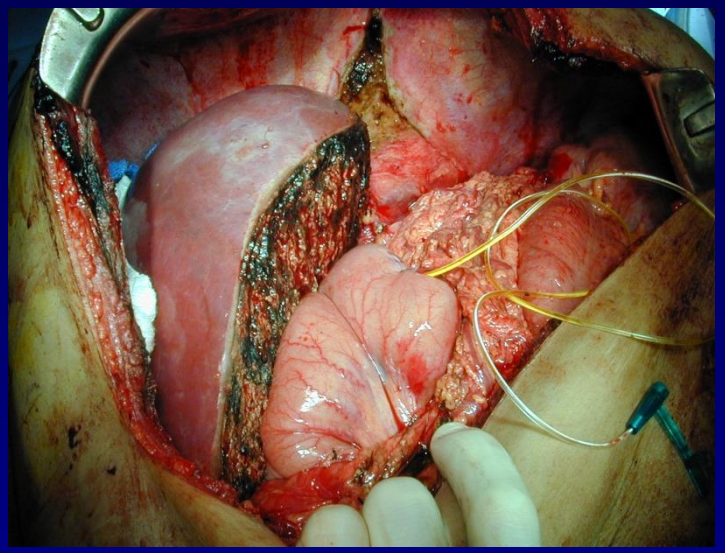
SonoSite™ 180
hand-carried ultrasound system



Color Power Doppler clearly demonstrates the middle and left hepatic vein.

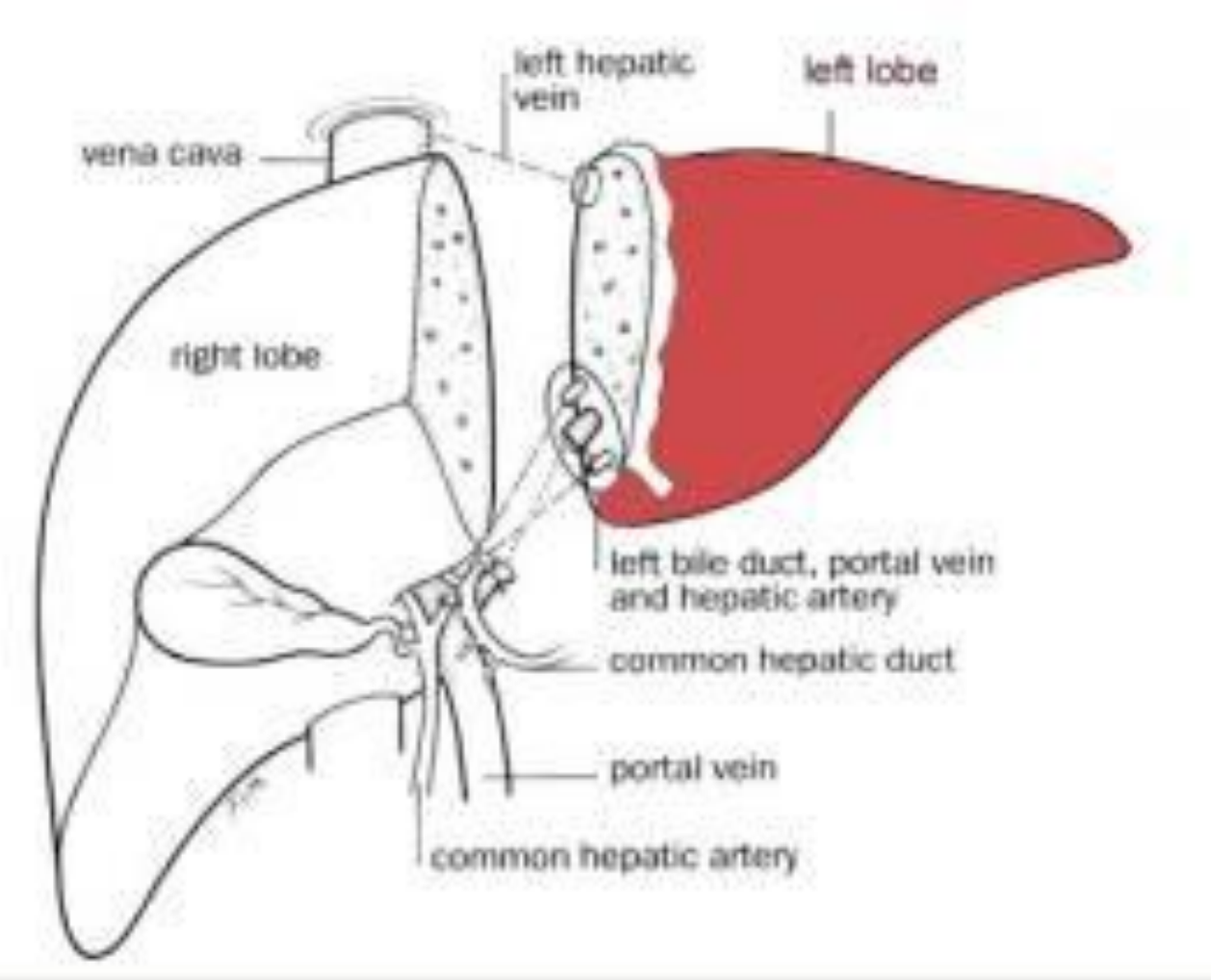
Live Donor Liver Transplantation

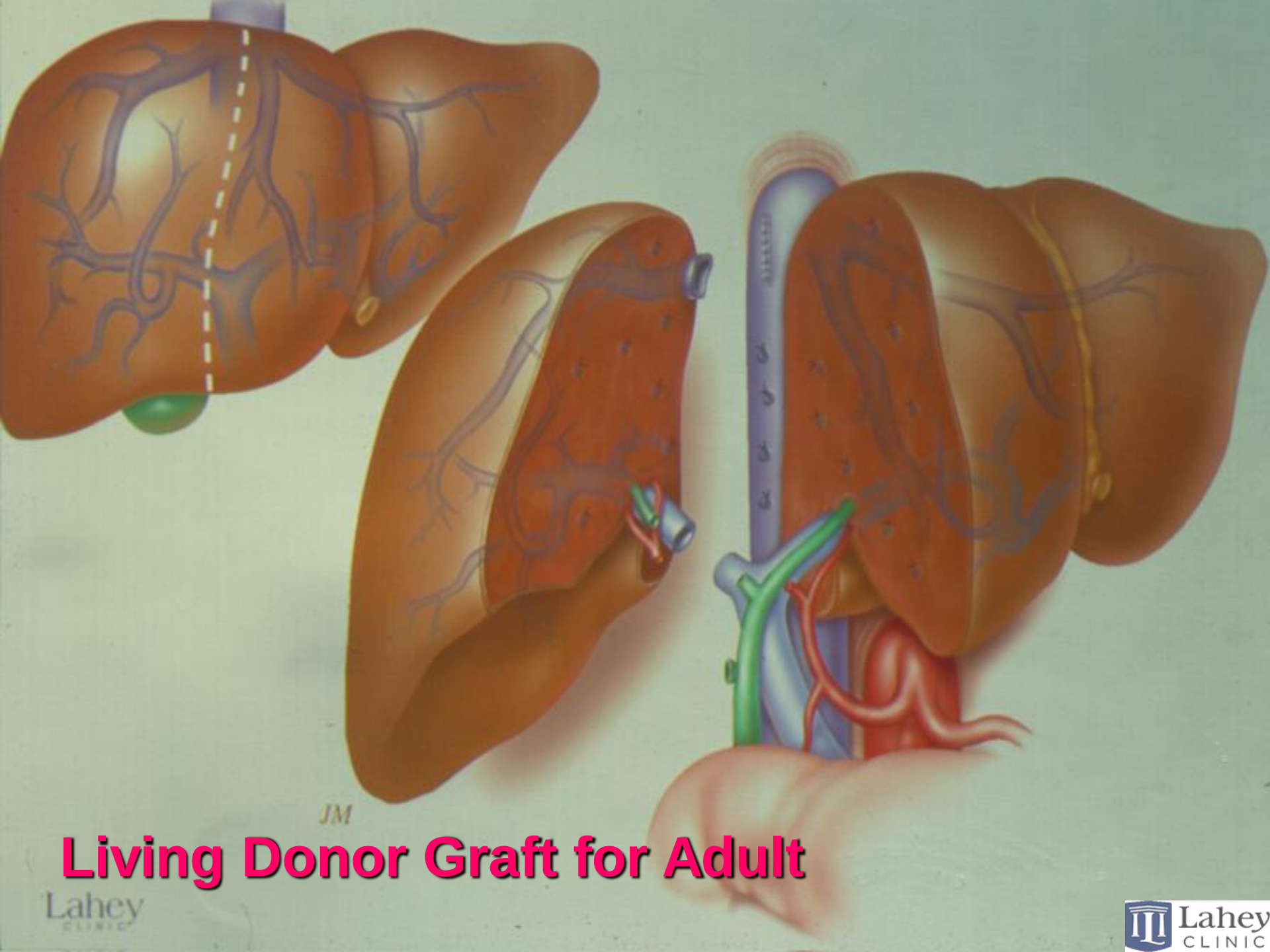




- Adult vs. Pediatric
- Right lobe (61%) vs. Left lobe (15%)
- Donor Selection and Preoperative Evaluation
- Surgical Techniques/Extent of Donor Hepatectomy

Living Donor Graft for Pediatric Recipient

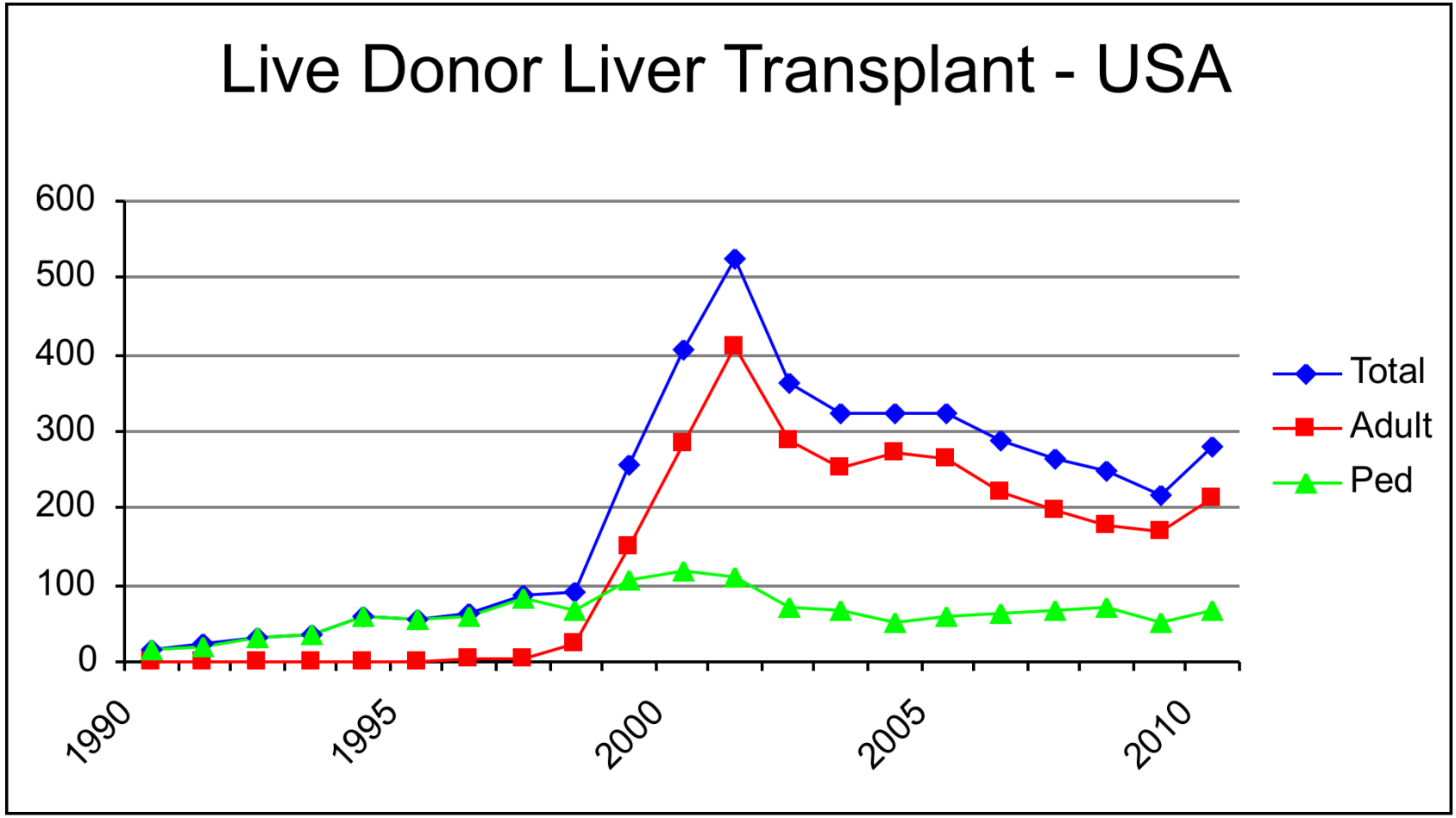




Living Donor Graft for Adult

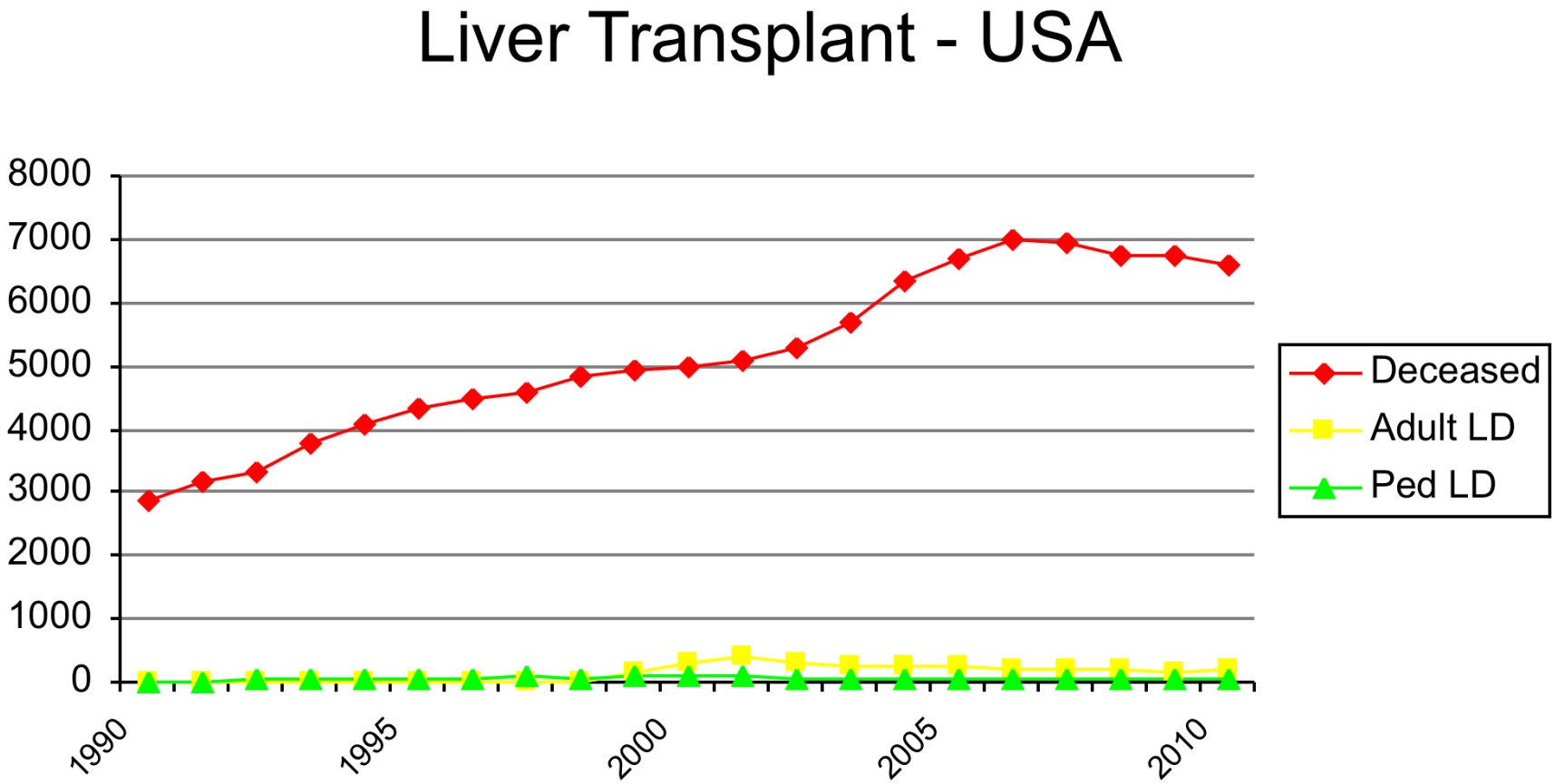
Living Donor Liver Transplantation

USA (OPTN Data)



Living Donor Liver Transplantation

USA (OPTN Data)



~ 4% of liver transplants are LDLT

Factors Influencing Donor Safety

- Program Experience
- Selection of Donors
  - Determination of Hepatic Volume and Anatomy
  - Pre-donation liver biopsy
- Extent of Donor Hepatectomy
- Post-operative complications
- Catastrophic Events

Living Donor Adult Liver Transplantation

USA (OPTN Data)

1990 – 2010 Activity

	Number of LDALT		
	1-49	50-99	>100
# of centers	59	6	13

- Of 78 centers, only 17% have performed > 100 LDALT in 20 years

Living Donor Adult Liver Transplantation

USA (OPTN Data)

2009 – 2010 Activity

	Number of LDALT				
	1	2	3 - 9	10 - 25	> 25
# of centers	7	4	13	10	5

- Of 39 centers, only 13% have performed > 25 LDALT in the past 2 years

Outcomes of 385 Adult-to-Adult Living Donor Liver Transplant Recipients: A Report From the A2ALL Consortium

Olthoff K et al. Ann. Surg. 2005; 242:314-325.

- **NIH sponsored study with 9 centers and 385 recipients**
- **3 month and 1-year graft survival: 87% and 81%**
- **13.2% of grafts fail within the first 90 days**
- **Center experience > 20 LDALT associated with a lower risk of graft failure.**
  - **Centers with < 20 associated with 83% higher risk of graft failure ($p<0.0045$)**

Factors Influencing Donor Safety

- Program Experience
- **Selection of Donors**
  - **Determination of Hepatic Volume and Anatomy**
  - **Pre-donation liver biopsy**
- Extent of Donor Hepatectomy
- Post-operative complications
- Catastrophic Events

A Report of the Vancouver Forum on the Care of the Live Organ Donor: Lung, Liver, Pancreas, Intestine Data and Medical Guidelines.

Barr ML, Belghiti J, Villamil FG, Pomfret EA, Sutherland DS, Gruessner RW, Langnas AN, Delmonico FL. *Transplantation.* 2006; 81(10): 1373-85.

Critical Components of the Living Donor Operation: Preop

1. Extensive, standardized donor evaluation: medical and psychosocial (IDA)

2. State of the art imaging for accurate volume measurements, definition of vascular and biliary anatomy

3. Informed consent process

DONOR EVALUATION FOR LDALT: PHASE I

YES — Recipient Acceptable Candidate for LDALT — NO

Potential Donor Identified

No Further Evaluation

Donor Information Packet Sent
Screening Labs & Blood Type Requested

Labs: LFT's, PT, PTT, BUN, Cr
Blood Type

Labs and Blood Type
Received and Reviewed

Compatible Blood Type
Normal Screening Labs

Incompatible Blood Type
and/or Abnormal Labs

Donor Meets with Transplant Surgeon

Donor Notified
No Further Evaluation

Donor Continues Evaluation

Donor Declines

Financial Coordinator
Insurance Approval

DONOR EVALUATION FOR LDALT: PHASE II

CT Scan
Volume, Morphology, and Vascular Anatomy

Medical &Psychosocial Evaluation:
Independent Donor Advocate MD's

Donor Not Suitable

History and Physical

Psychiatrist
Social Worker
Transplant Nurse

Labs & Serologies
CXR, EKG, US
Additional Tests

Medical, Psychosocial and Laboratory Data
Reviewed by Screening Committee

Donor Accepted

Donor Not Accepted

DONOR EVALUATION FOR LDALT: PHASE III

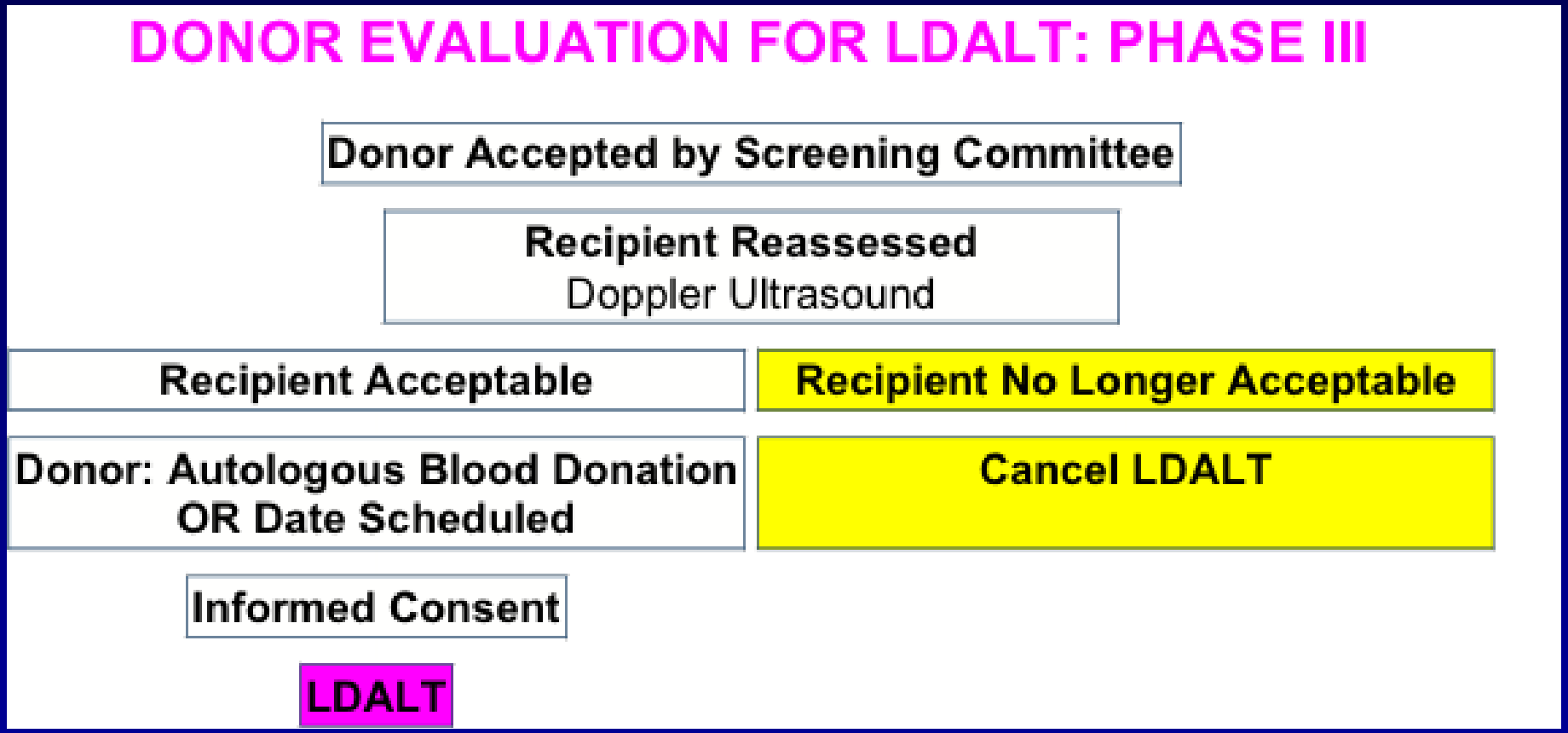
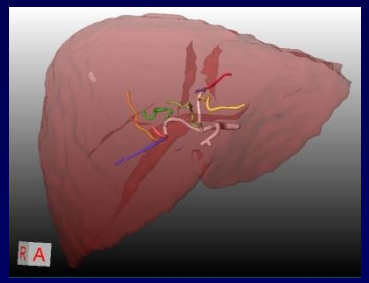
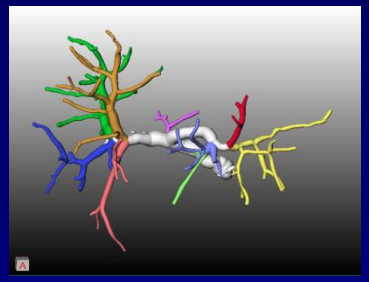


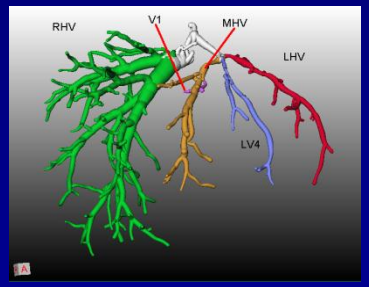
Image Analysis



Arterial Anatomy



Portal Venous Anatomy

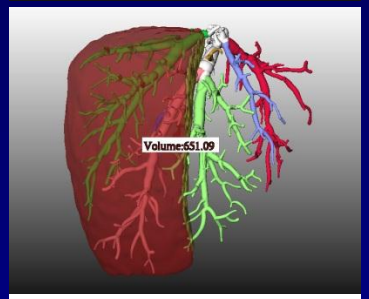


Hepatic Venous Anatomy

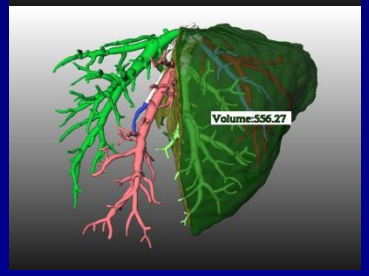
Biliary Anatomy

Total Liver Volume

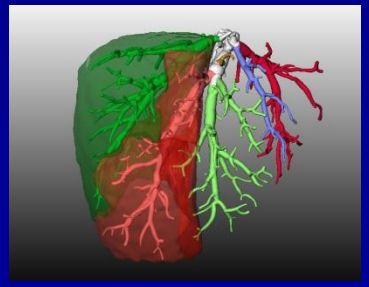
Graft Volume



Remnant Volume

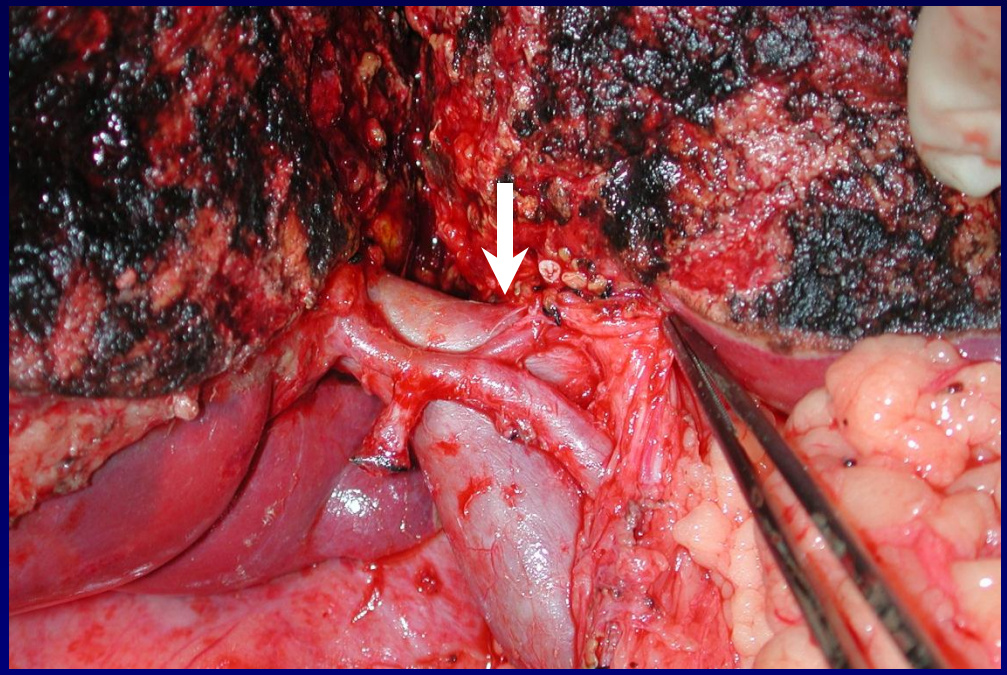


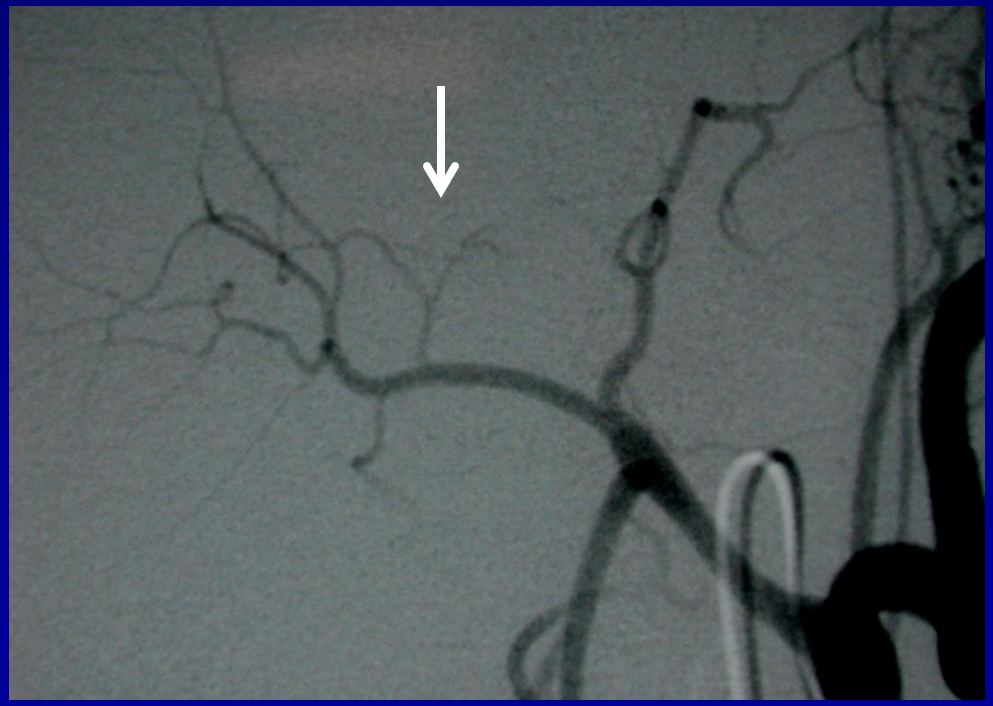
“Graft at Risk”



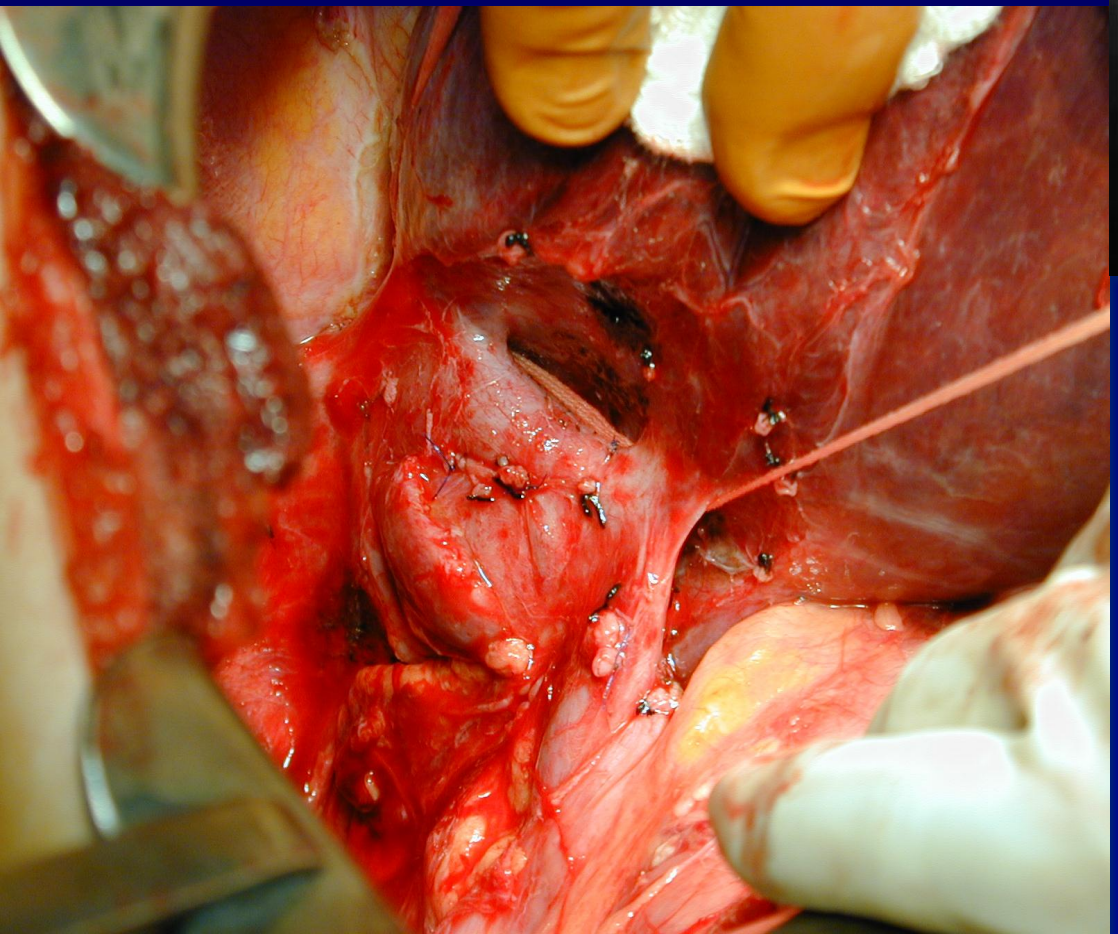
Segment IV Hepatic Artery

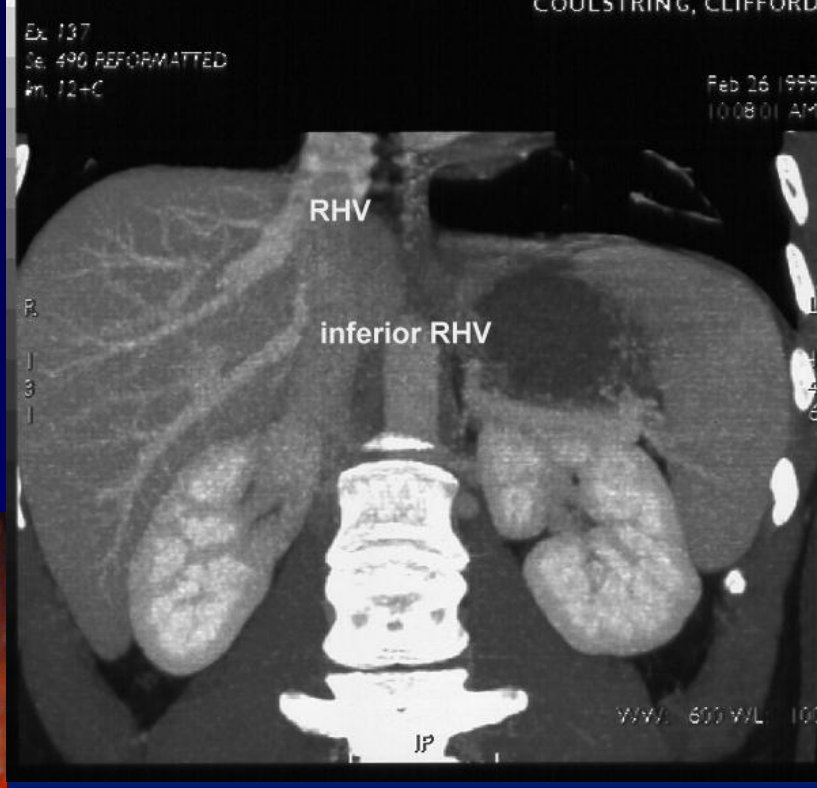
Compromise of the arterial supply to segment IV is associated with an increased incidence of biliary complications in the donor





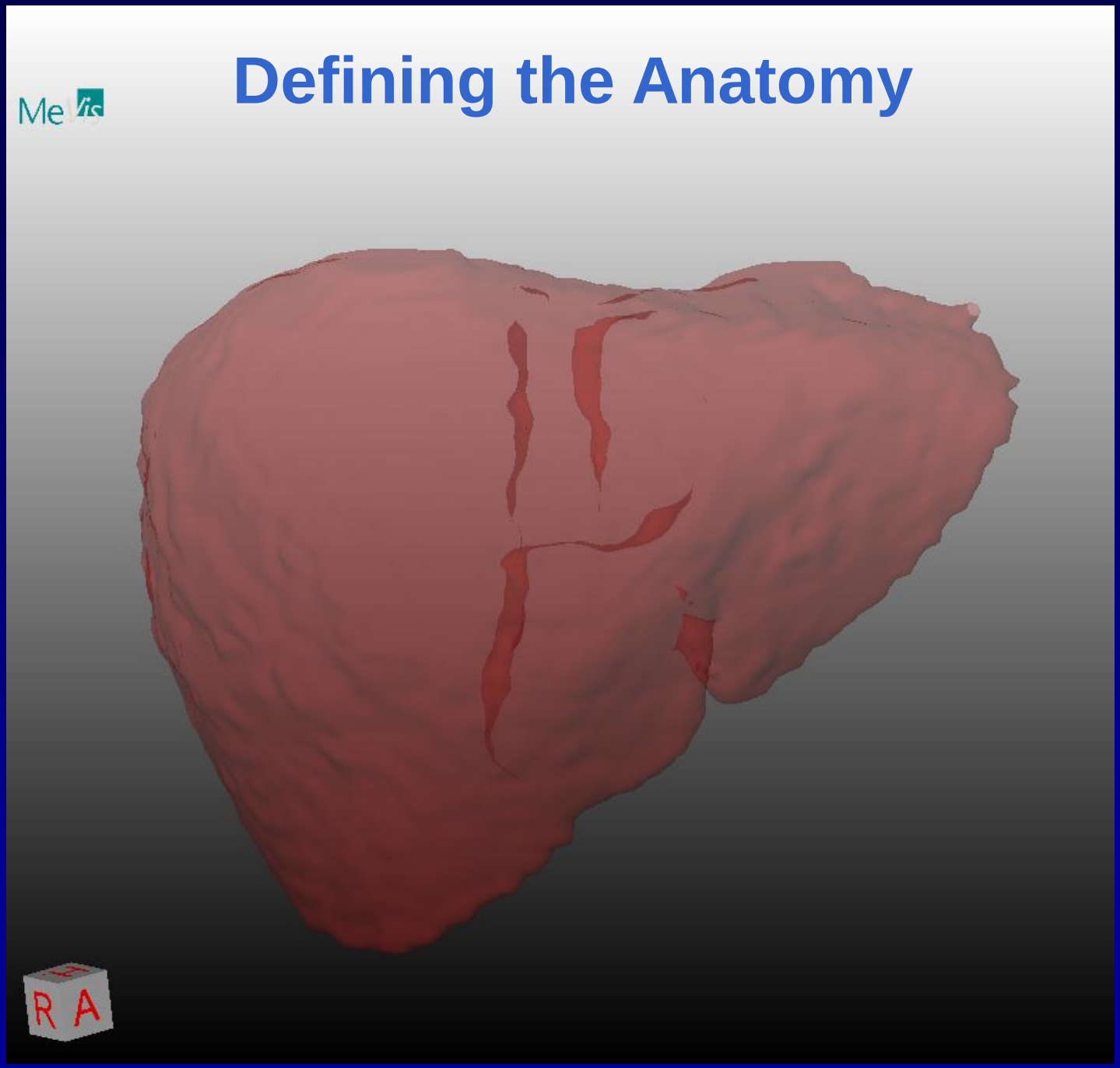
Accessory or Inferior RHV Reconstruction



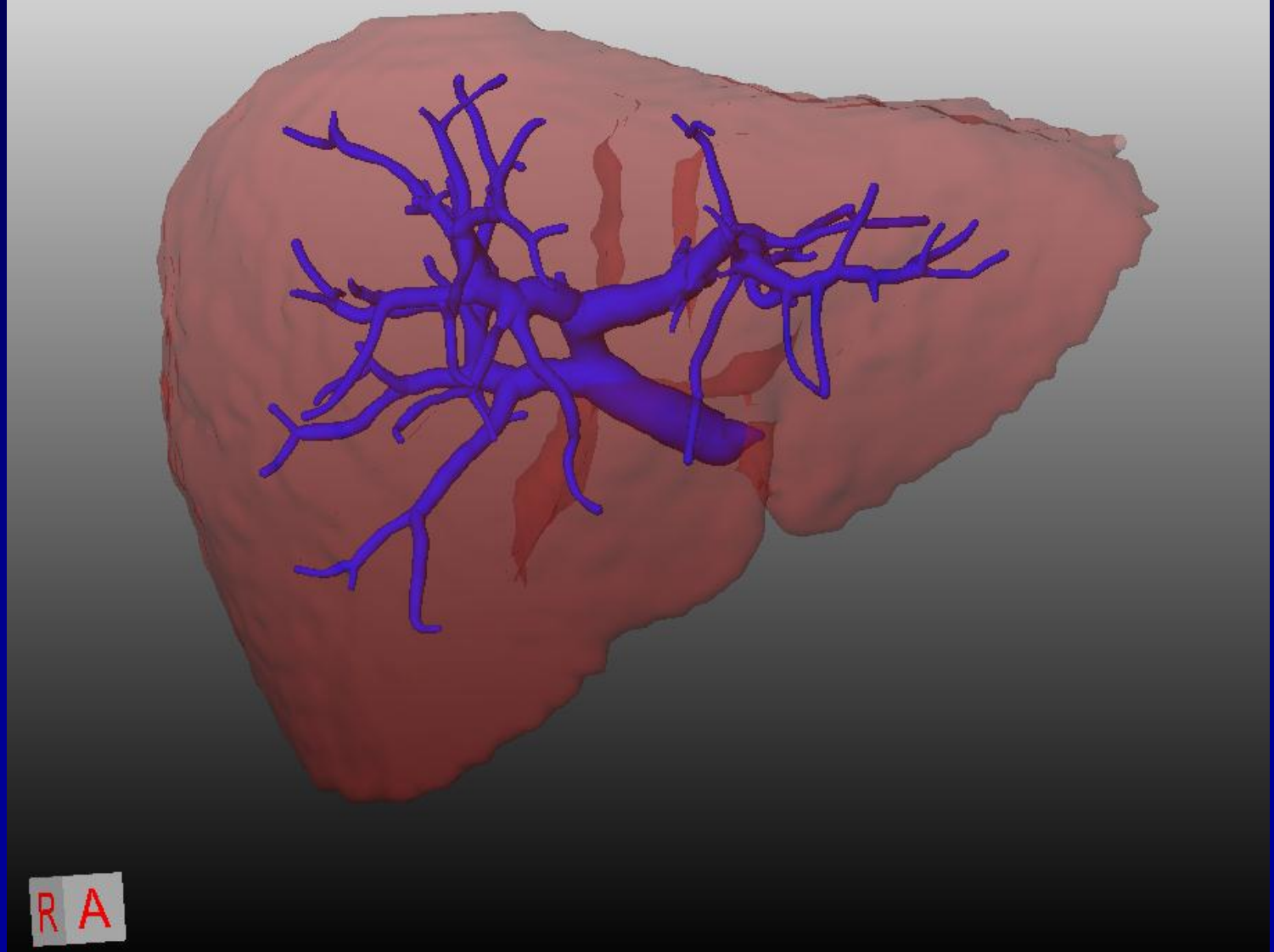


Reconstruct IRHV ≥ 5mm

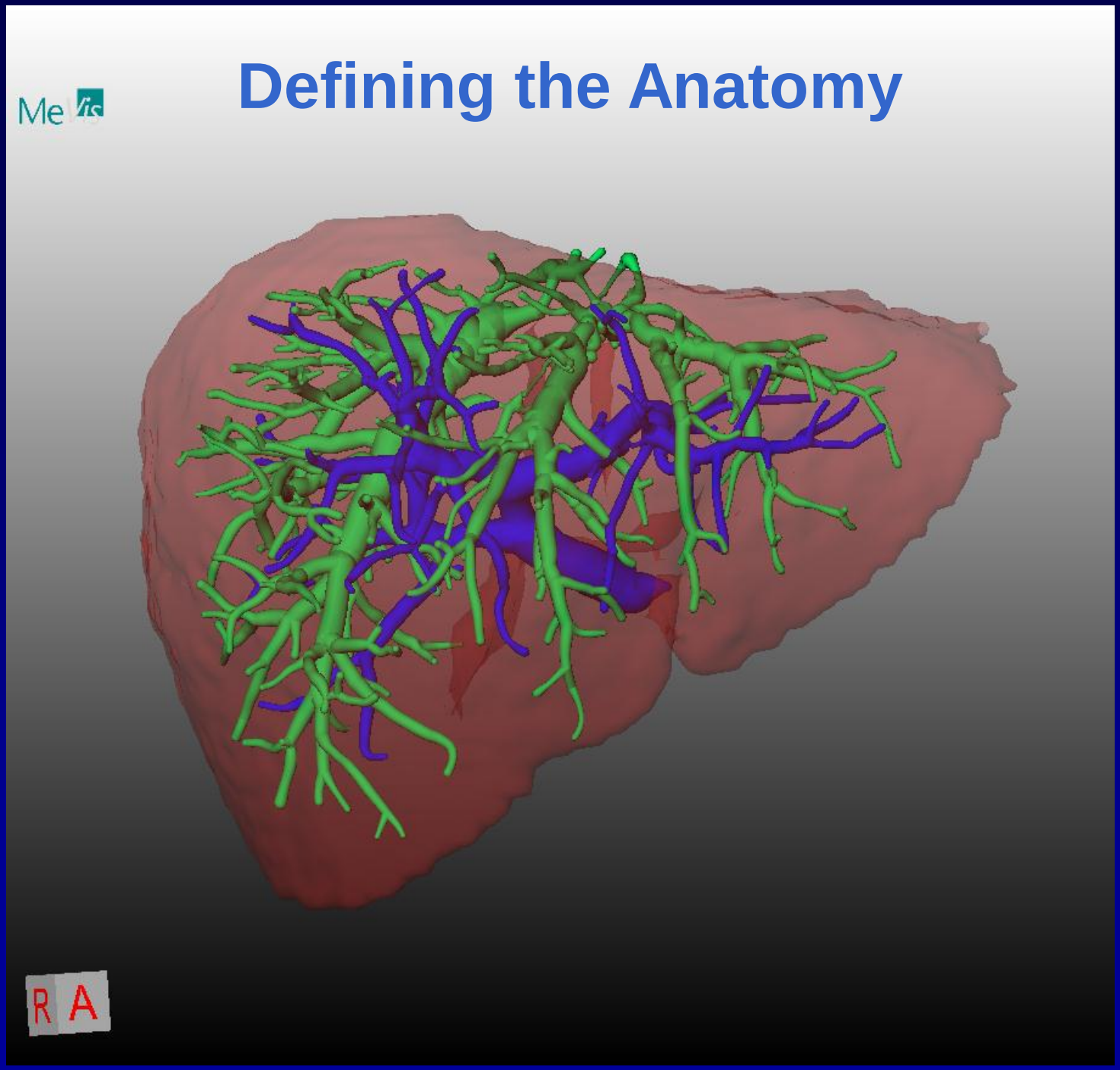
Defining the Anatomy



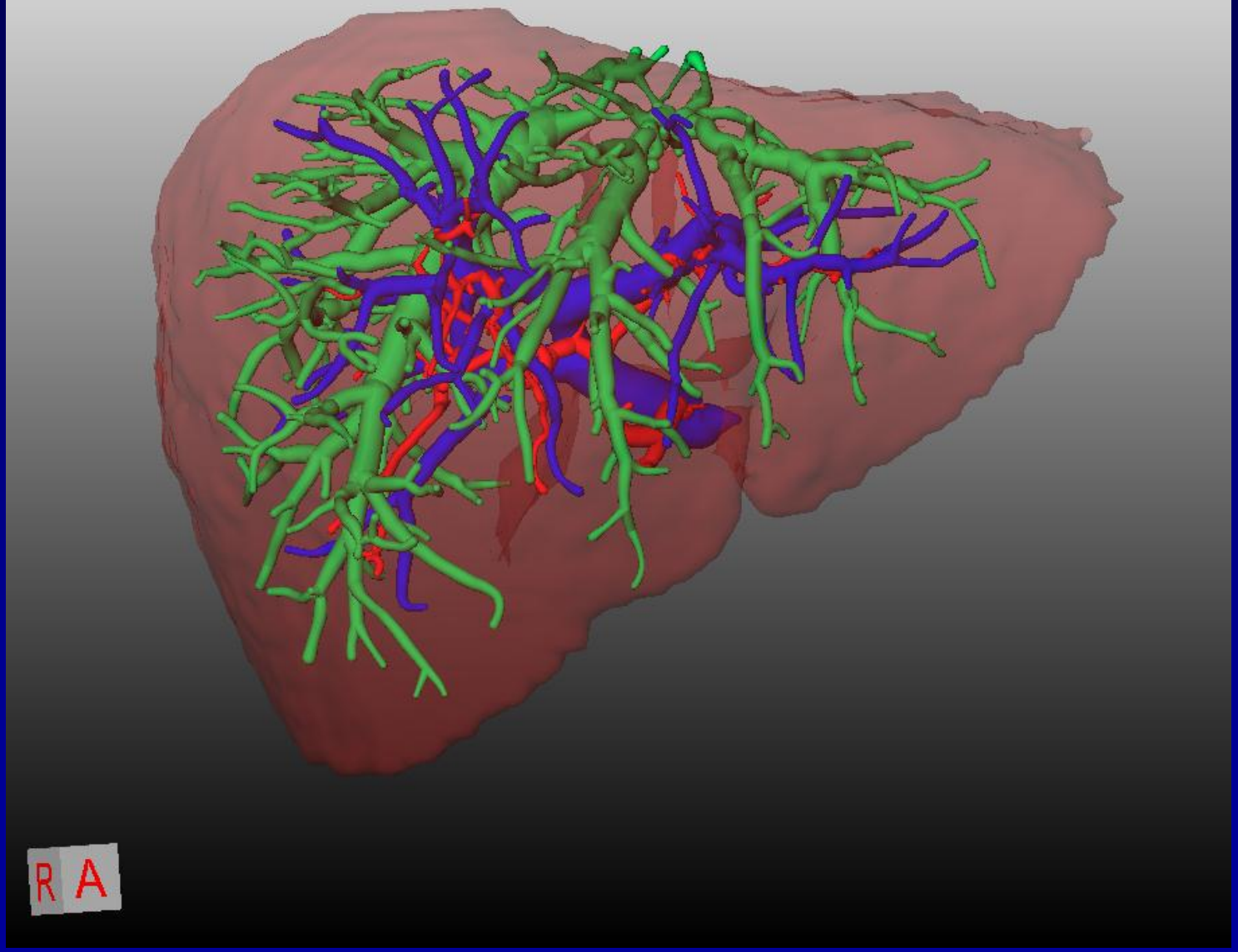
Defining the Anatomy



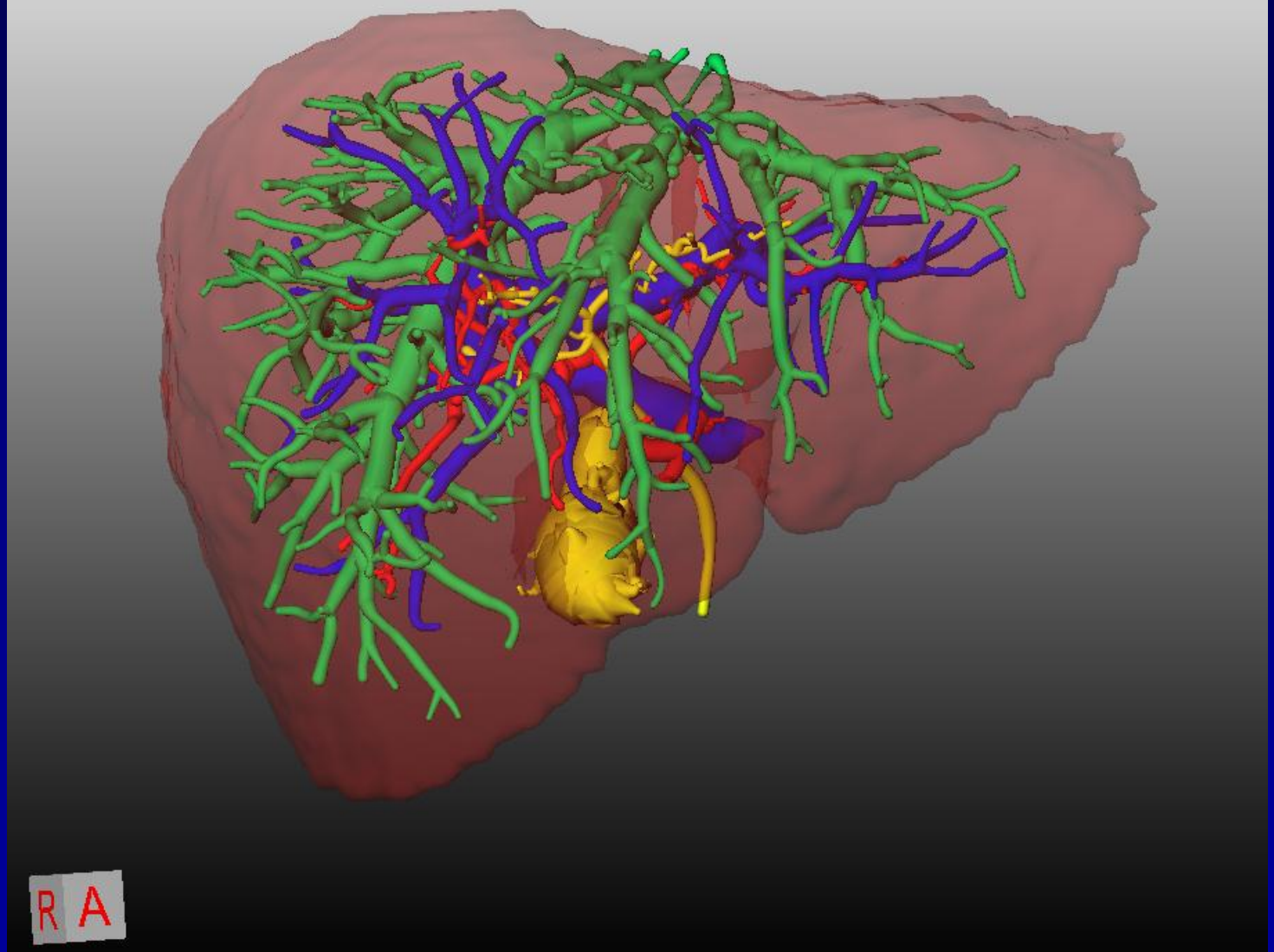
Defining the Anatomy

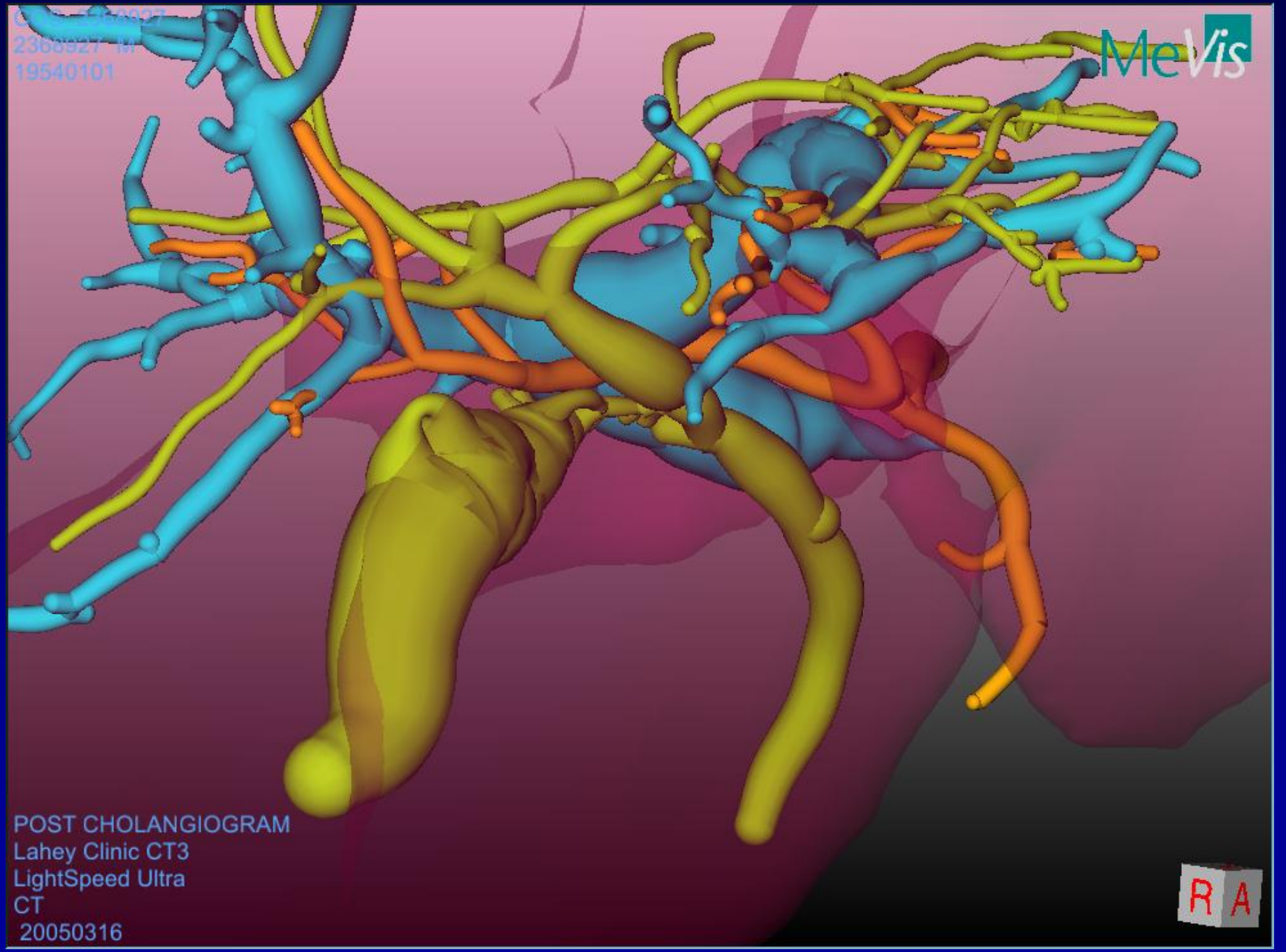


Defining the Anatomy

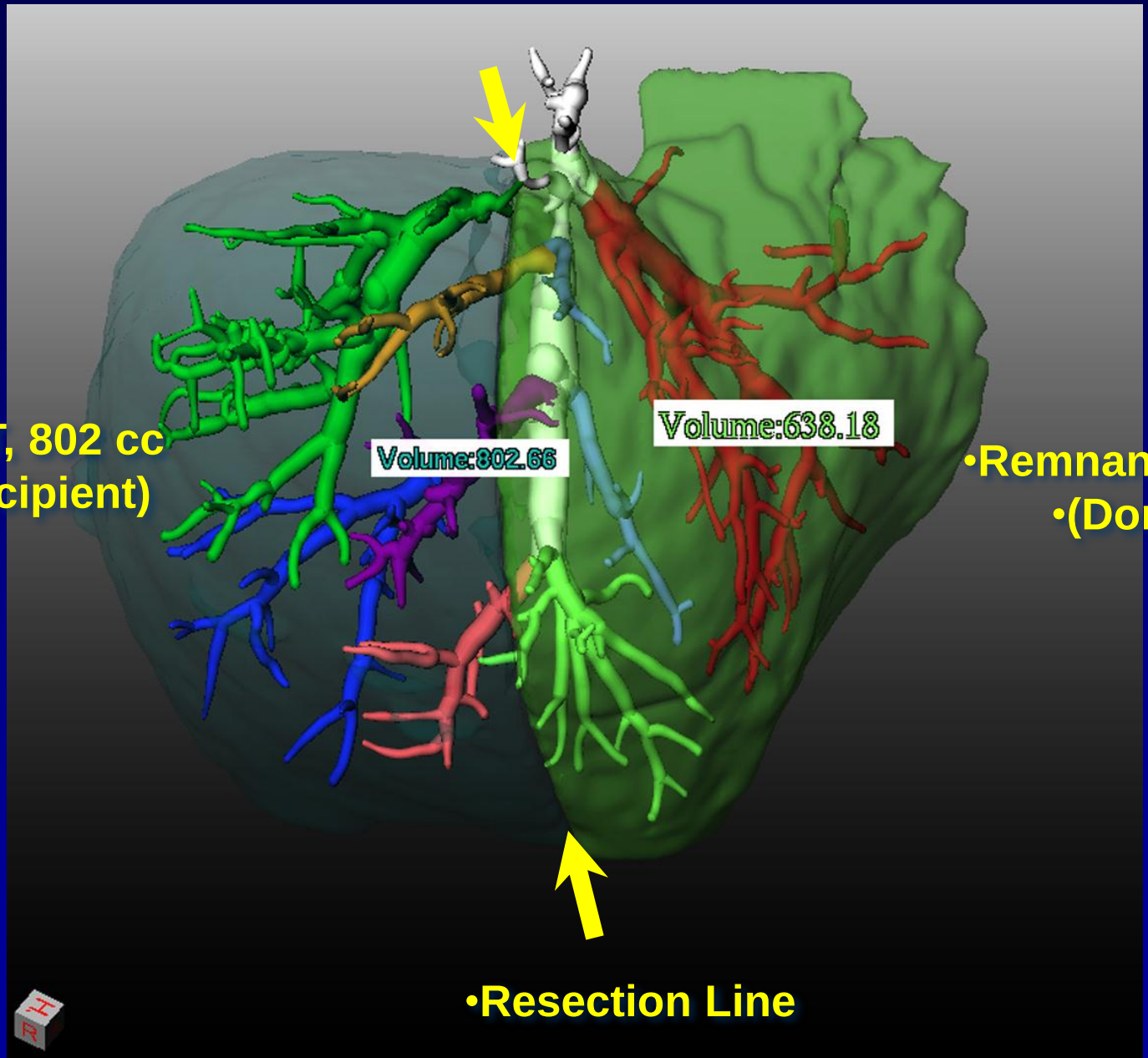


Defining the Anatomy




19540101
MeVis
POST CHOLANGIOGRAM
Lahey Clinic CT3
LightSpeed Ultra
CT
20050316
R
A

Virtual Resection/Volume Analysis



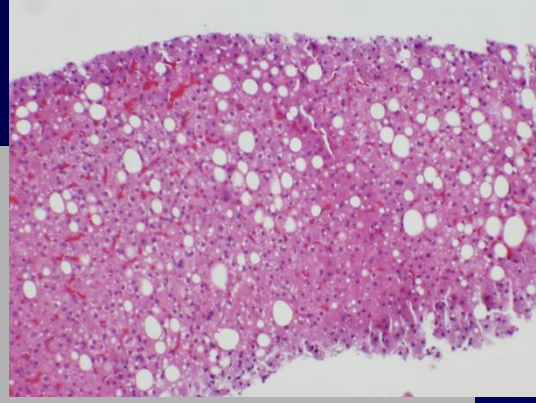
•GRAFT, 802 cc
•(Recipient)

•Remnant, 638cc
•(Donor)

•Resection Line

Routine vs. selective pre-donation liver biopsy remains controversial for assuring the safety of right lobe liver donors.

Biopsy used to assess for macrosteatosis or other signs of liver disease.



Liver Biopsy

BMI is not always reliable.

Table 1. Profiles of 9 Living Donors Who Reduced Their Body Weight for Liver Donation

Case No.	Gender/ Age	Weight (Kg) 1st	Weight (Kg) 2nd	Interval (mos)	BMI 1st	BMI 2nd	Degree of Hepatic Steatosis: Radiological Study 1st	Radiological Study 2nd	Histological Study 1st	Histological Study 2nd
1	M/20	62	59	5	21	20	Moderate	No	95% (15 + 80)	20% (10 + 10)
2	M/39	79	74	3	27	25	Severe	Moderate	70% (55 + 15)	60% (40 + 20)
3	M/31	73	70	2	23	22	No	No	25% (5 + 20)	5% (5 + 0)
4	M/22	78	76	5	26	25	Mild	Mild	25% (15 + 10)	20% (15 + 5)
5	M/25	66	60	3	21	19	Mild	No	35% (15 + 20)	10% (10 + 0)
6	M/18	73	68	6	24	22	Moderate	Mild	75% (15 + 60)	15% (10 + 5)
7	M/43	68	65	2	24	23	Mild	No	40% (10 + 30)	10% (10 + 0)
8	M/42	80	74	4	31	28	Mild	No	25% (10 + 15)	15% (10 + 5)
9	M/25	91	85	2	31	29	Moderate	Mild	50% (30 + 20)	25% (20 + 5)

Abbreviation: BMI, body mass index.
Interval means the intervening period between the first and second percutaneous liver biopsies. Radiological study included ultrasonography and triphasic computed tomogram. Data of histological study were expressed as "the sum of steatosis (macrovesicular steatosis + microvesicular steatosis)."

Liver Transplantation, Vol 10, No 6 (June), 2004: pp 721–725

No biopsy-related complication in consecutive 1162 donors

Lahey Clinic: Donor Selective Liver Biopsy Protocol

Simpson MA et al. *AJT* 2008 8:832-38

Indications for selective liver biopsy:

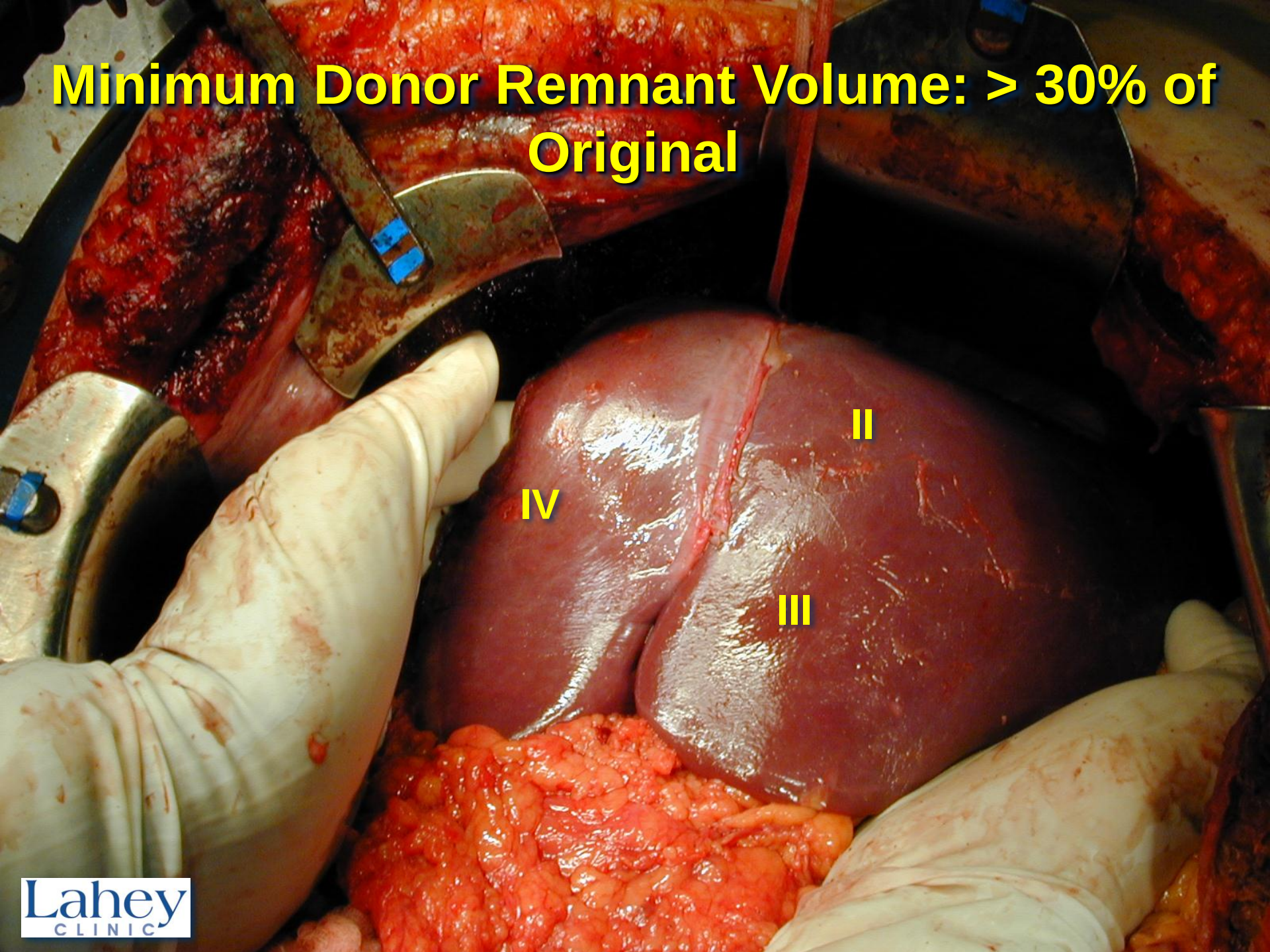
1. Any abnormality of blood liver function tests or + results for hepatitis or antinuclear antibody serologies
2. Imaging studies suggestive of steatosis or other parenchymal abnormality
3. BMI ≥ 28
4. Genetic relation to a recipient with or family history of immune mediated liver disease – usually autoimmune hepatitis, primary sclerosing cholangitis, or primary biliary cirrhosis
5. Prior history of substance abuse

Extent of Donor Surgery

- The **amount of remnant hepatic parenchyma** in the donor after hepatectomy has been repeatedly identified as the **single most important predictive factor for donor outcome**.

- Individuals with **larger remnant volumes** consistently display **fewer adverse events**, shorter lengths of stays, and faster return to pre-donation activity levels

Minimum Donor Remnant Volume: > 30% of Original



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Living Donor Adult Liver Transplantation
Donor Outcomes - Early

Donor Morbidity

- A2ALL *(Ghobrial et al. Gastroenterology 2008;135:468)*
  - 38% of 405 donors
    - 21% - 1 complication; 17% - 2+ complications

Grade (% of complications):
- Grade 1 - 48%
- Grade 2 - 47%
- Grade 3 - 2%
- Grade 4 - 3 deaths

Events (% of patients):
- Biliary leak – 9%
- Reoperation – 3%
- Venous thrombosis: PV-2, IVC-1
- Incisional hernia - 6%

- University of Toronto *(Adcock et al Am J Transpl 2010;10:364-71*
  - 41% of 202 donors
    - Grade 1 – 30%
    - Grade 2 – 26%
    - Grade 3 – 44% (1/2 were pleural effusions)
    - Grade 4 - 0
  - Reoperation 2.5%

Living Donor Hepatectomy: The Importance of the Residual Liver Volume

LIVER TRANSPLANTATION 17:1404-1411, 2011

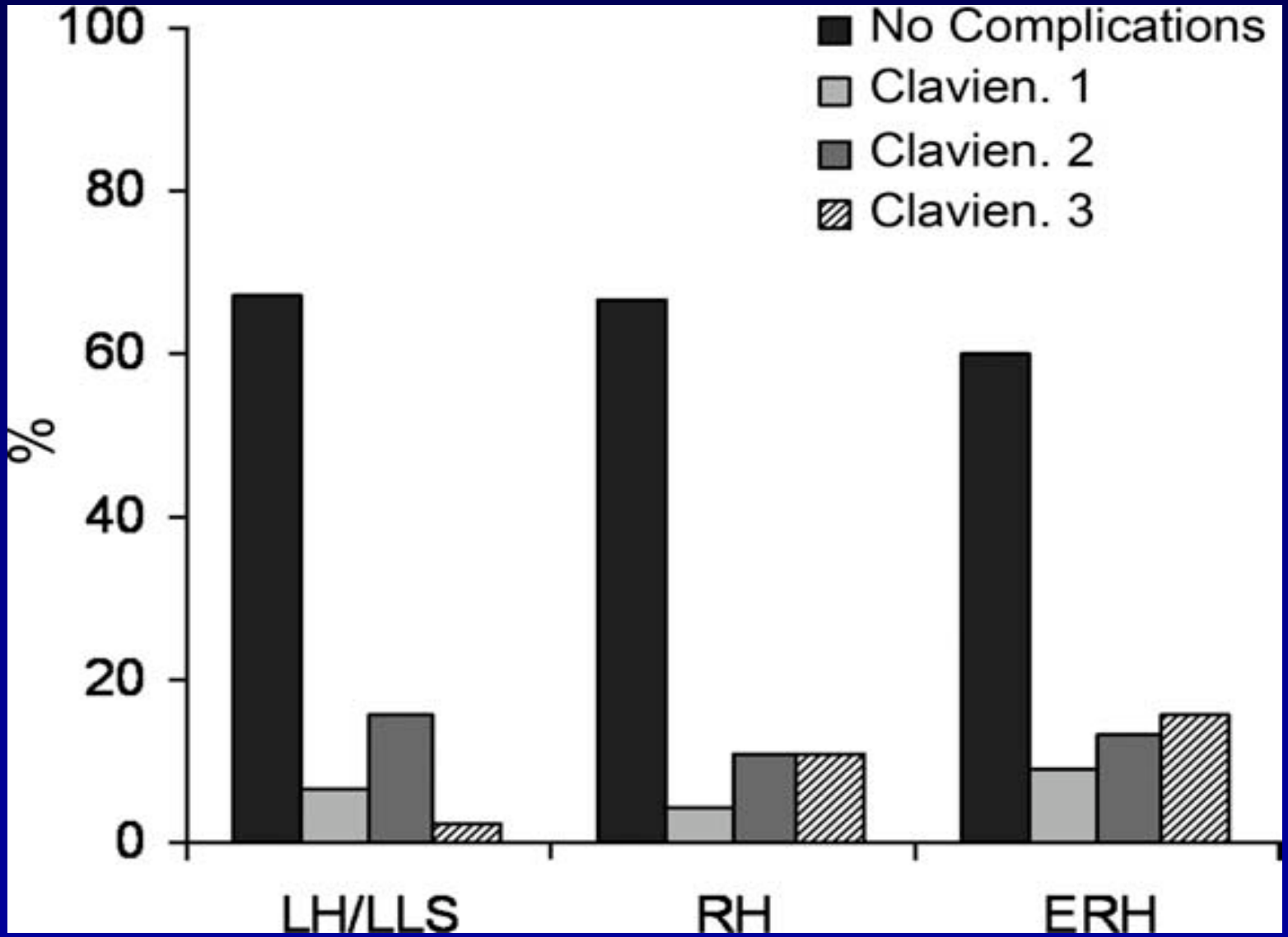
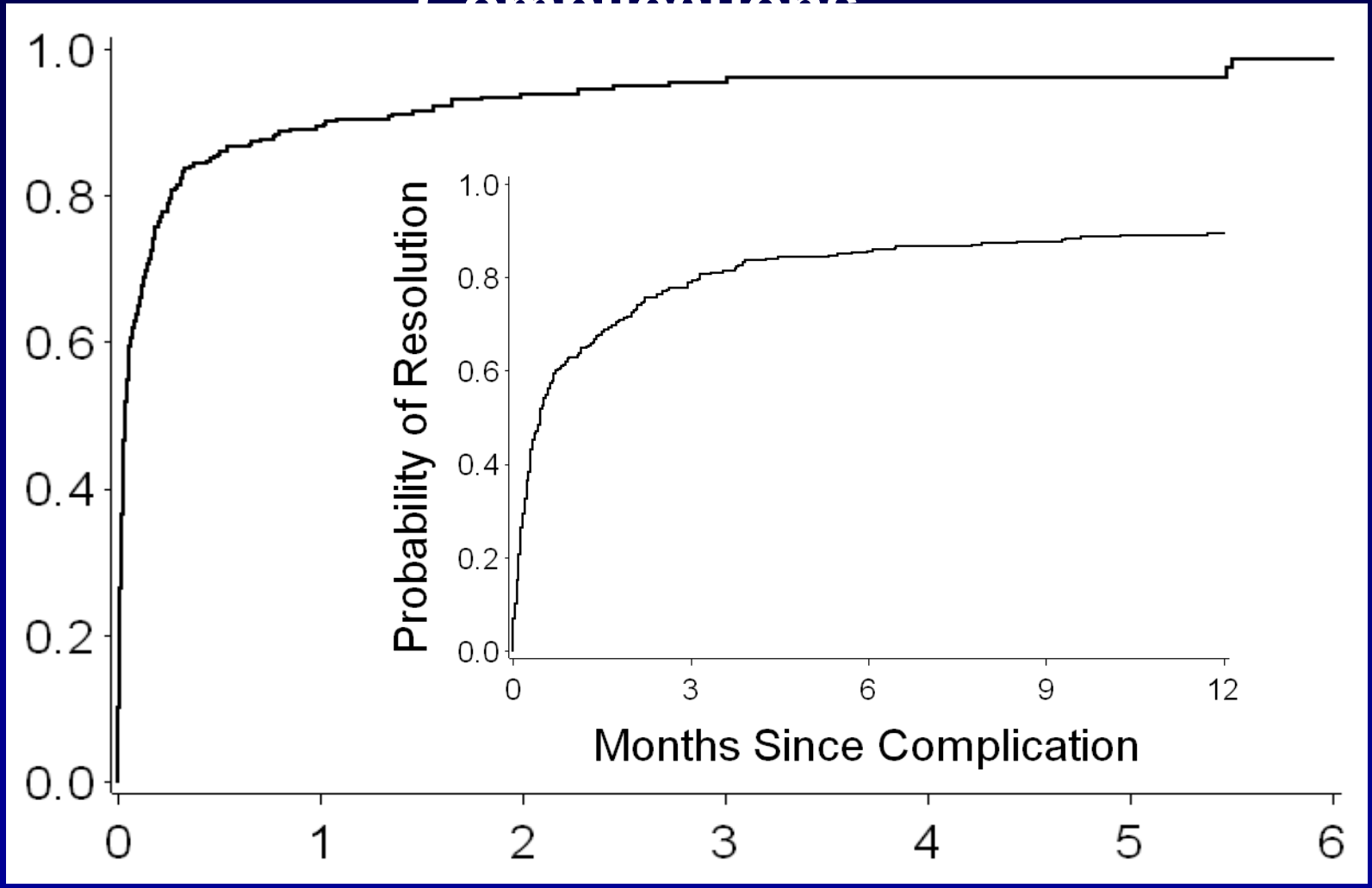


Figure 3A. Time to Resolution of all Complications



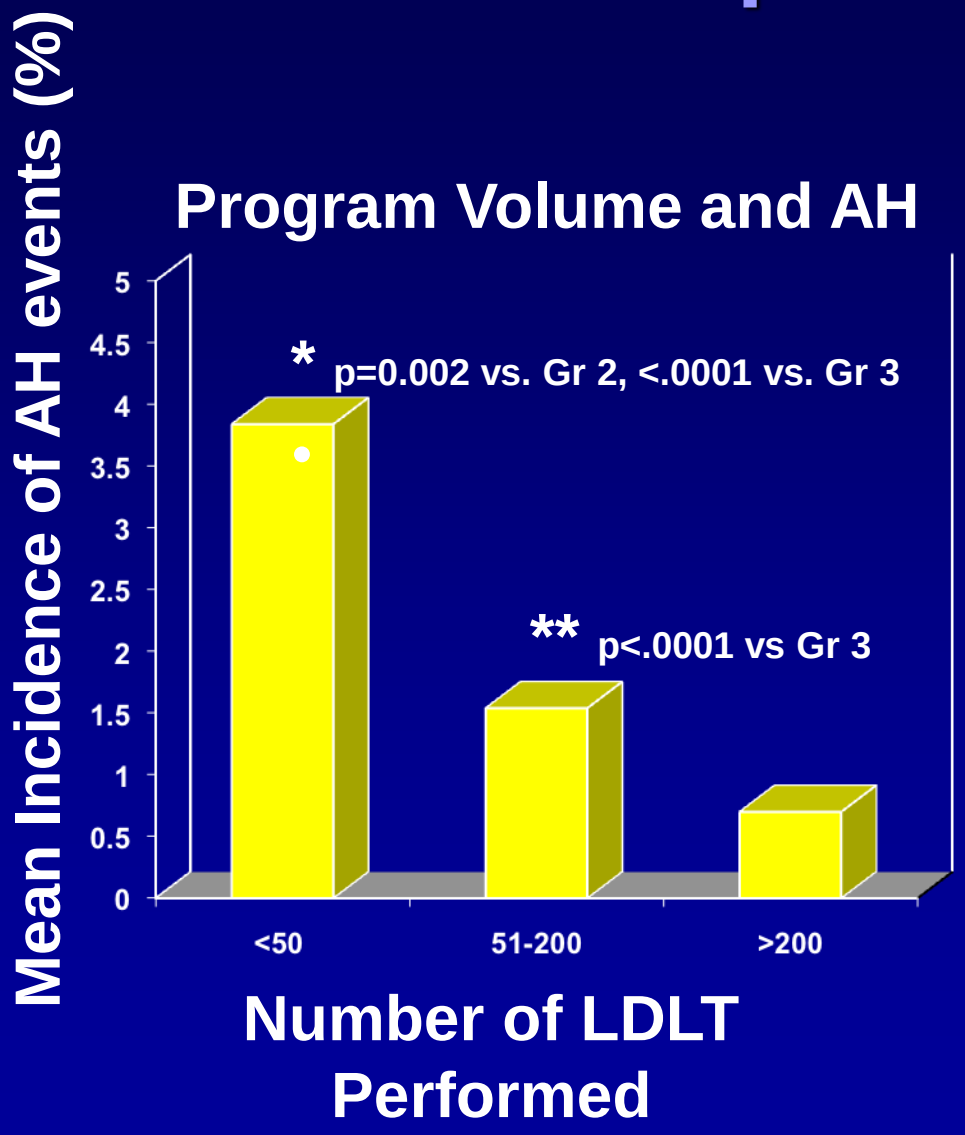
The Incidence of Death and Potentially Life-Threatening "Near Miss" Events in Living Donor Hepatic Lobectomy: A World-Wide Survey

Liver Transplantation 2012

“Near Miss” Survey

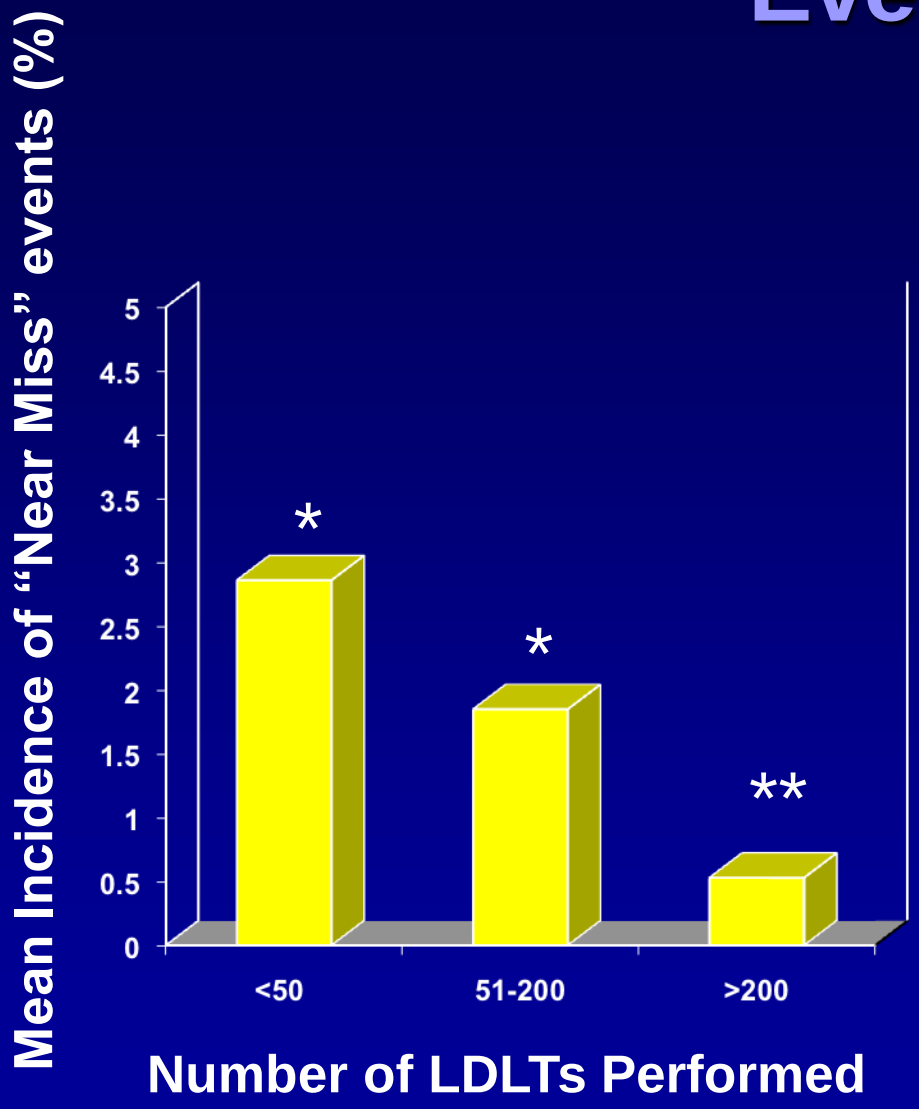
- For the purpose of this survey, "near miss" is defined as **an event or events with potentially fatal consequences.**
  - Severe bradycardia during the donor surgery, displacement of an arterial clip, need for the donor to be listed for liver transplantation, etc.
- Report this type of event even though the situation may have been successfully managed and the donor suffered no lasting ill effects.

Program Volume and Aborted Hepatectomy



- 11,553 completed donor hepatectomies reported
- An additional 136 donor hepatectomies were aborted
- Prospective donors face 1.16% overall risk of aborted hepatectomy (136/11689)
- However, high volume programs experience significantly fewer AHs (>200 = 62/8860, 0.7%)

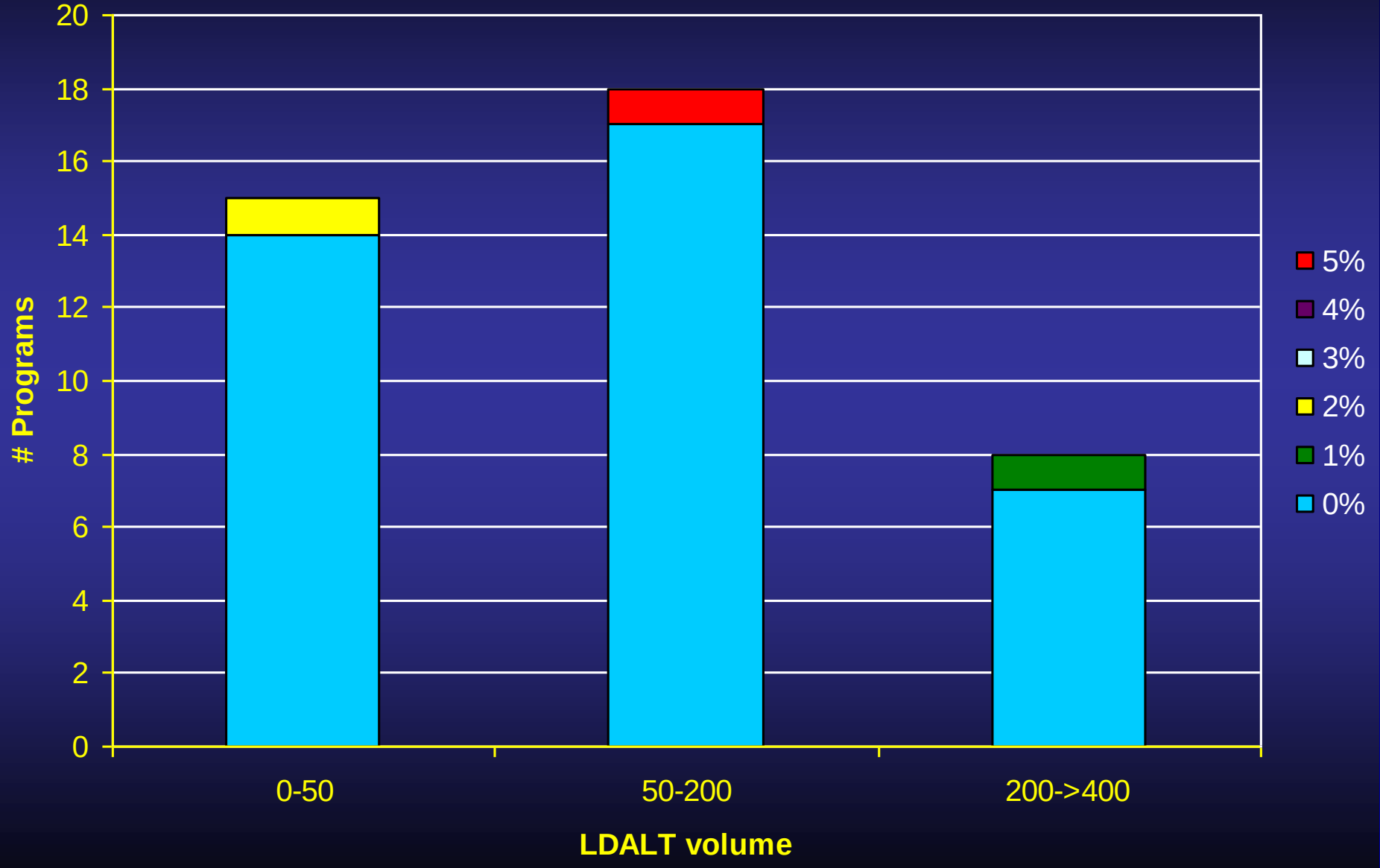
Program Volume and "Near Miss" Events



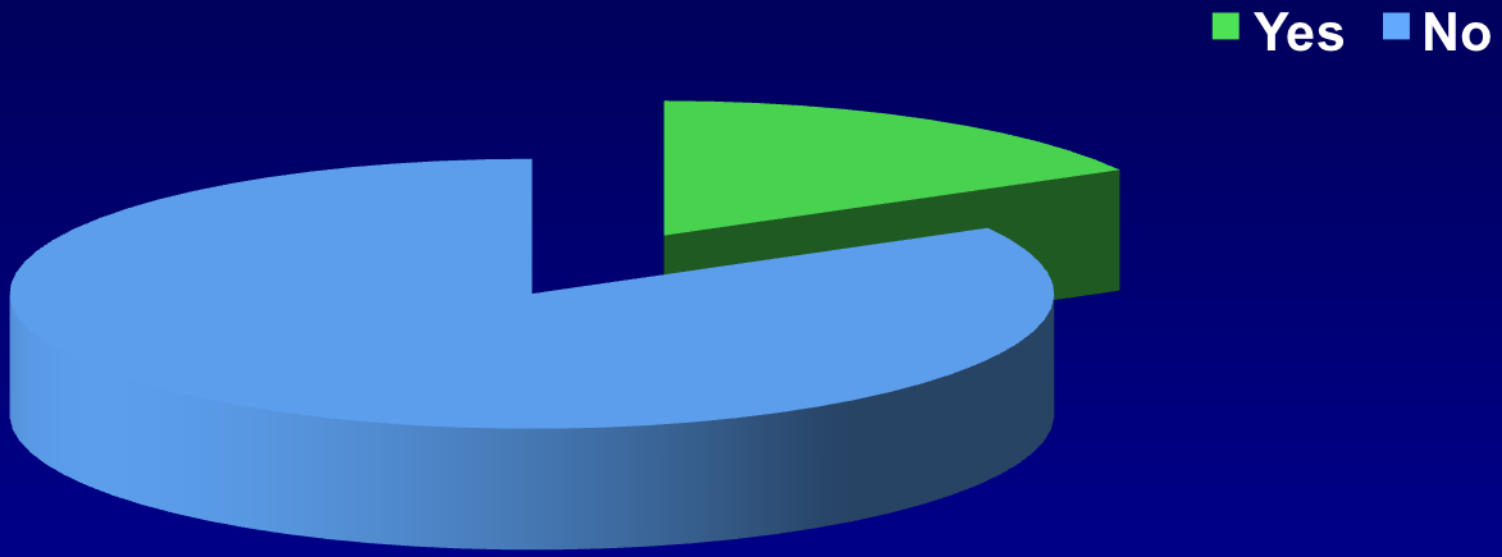
- "Near Miss" events decreases with experience
- The difference between low and medium volume program trends, but does not reach significance (*p=0.1)
- Both low and medium volume programs have higher incidence of near miss events compared to high volume programs (**p<0.001, both groups)

LDALT Volume & Donor Requiring Liver Transplant

1 center in each group has had a donor requiring LT



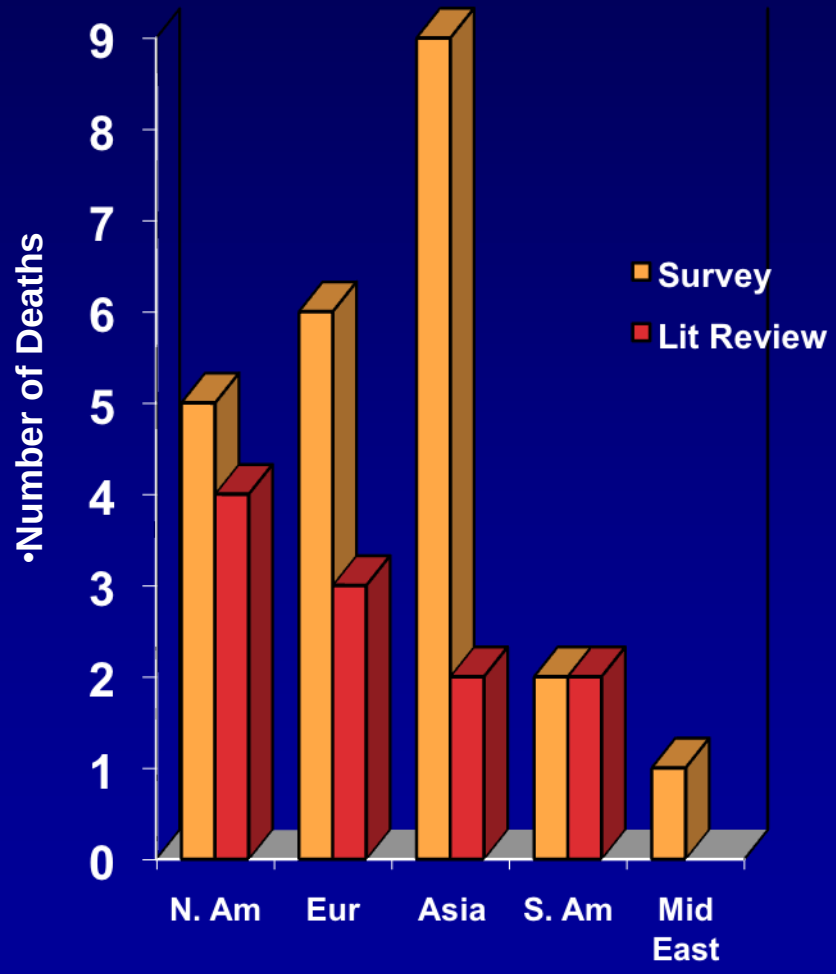
Have there been any donor deaths in your program?



- 71 Responses
- 59 with no deaths
- 12 centers with 18 deaths

- 8 Centers with single death
- 2 Centers with 2 deaths each
- 2 Centers with 3 deaths each
- (5 deaths reported by ELTR not seen in individual response)

36 Total Donor Deaths by Geographic Region

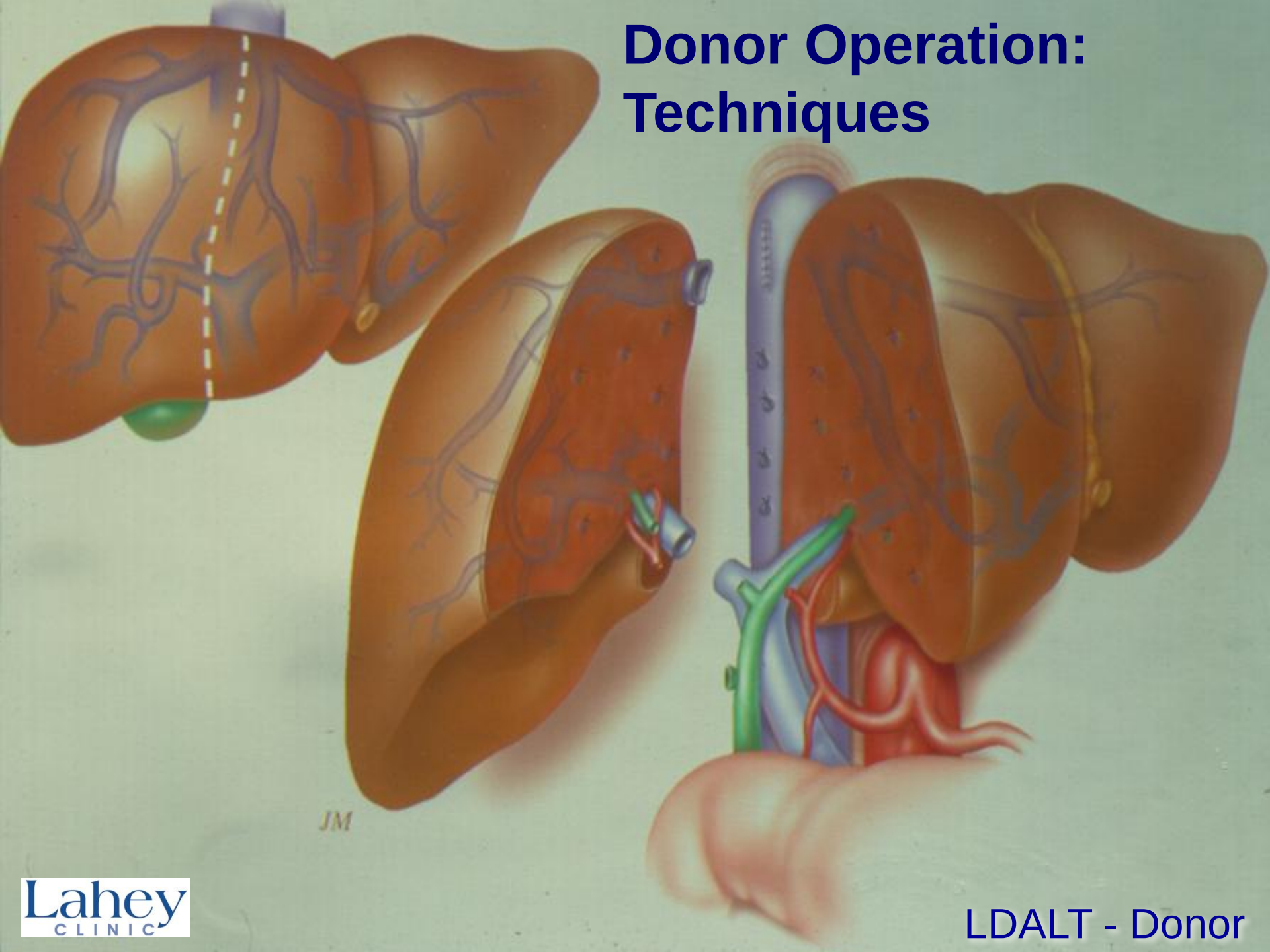


- Deaths reported in survey (n=23)
  - 15 ≤ 60 days Post Op
  - 8 >60 days Post Op, but 2 result of continuing complications
- Deaths reported in literature (n=11)
  - 8 in first 60 days
  - 3 >60 days
- 2 Additional Deaths known but not reported to either

“Near Miss” Events Occur in Addition to Reported Complications and Deaths

- 61% of programs included in the survey reported a “near miss event”
- 127 Events in 126 Patients (43 Programs)
- 1% Overall incidence of a “Near Miss” Event (127/11553=1.1%)

Donor Operation: Techniques



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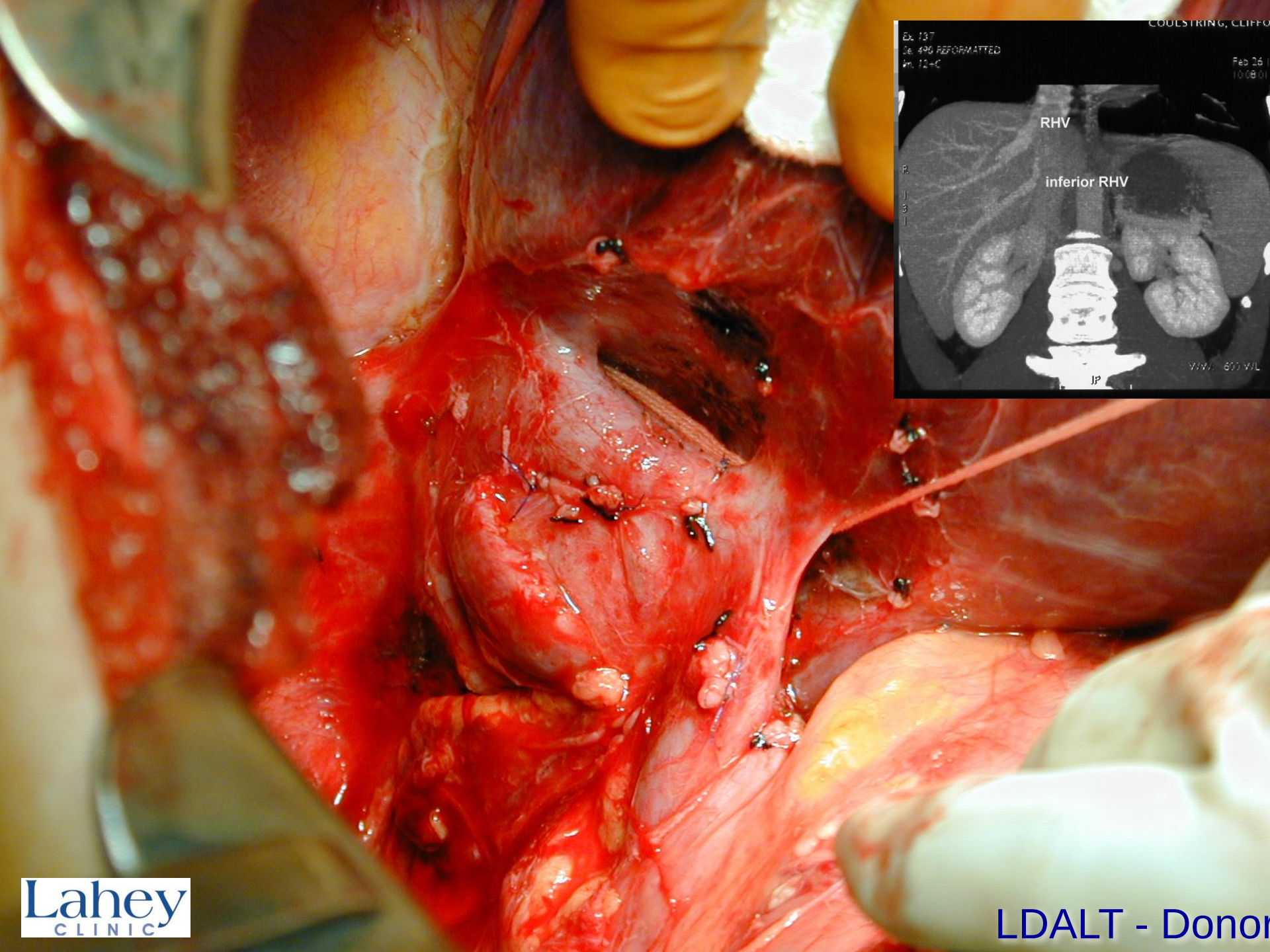

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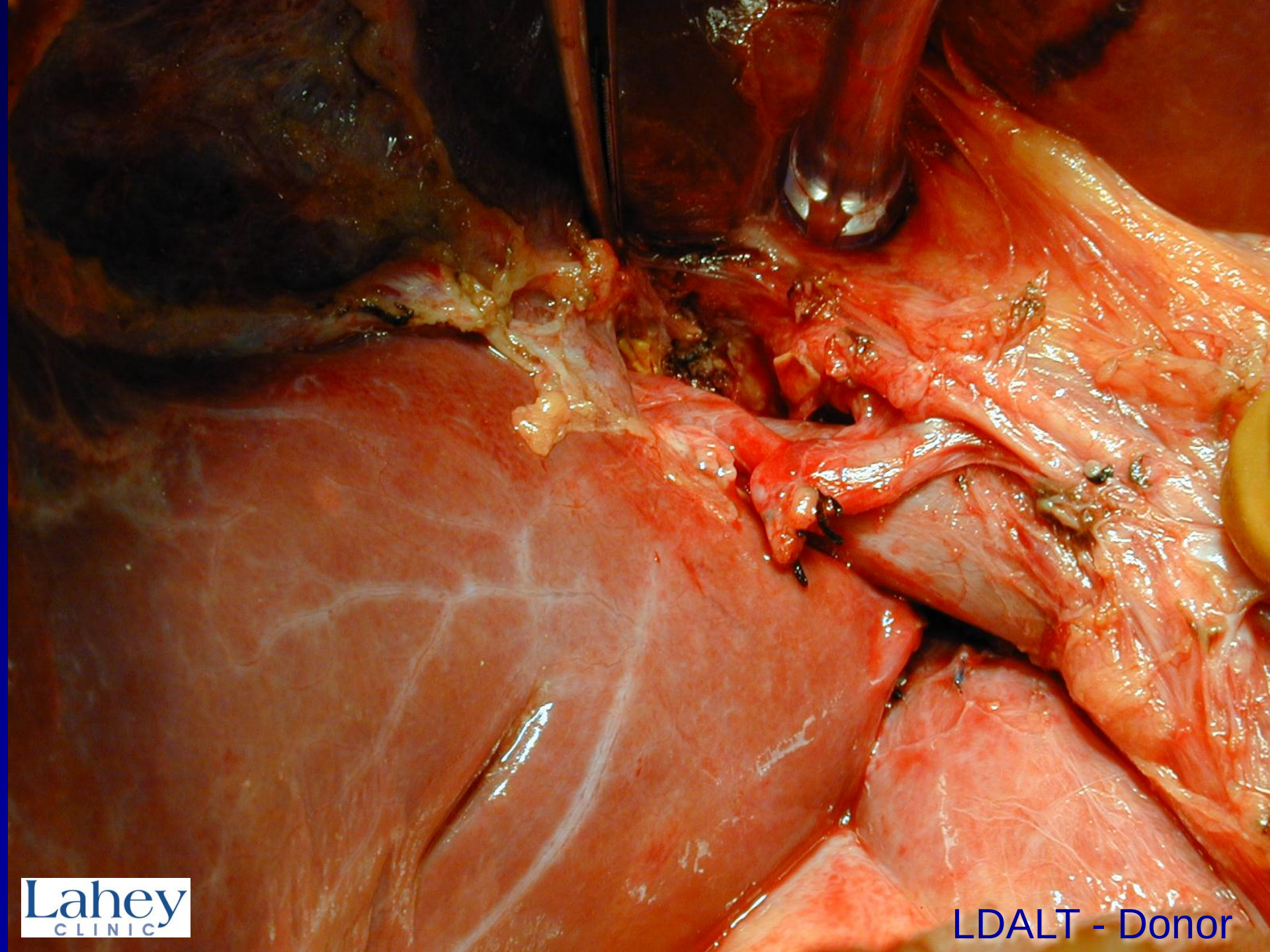
LDALT - Donor



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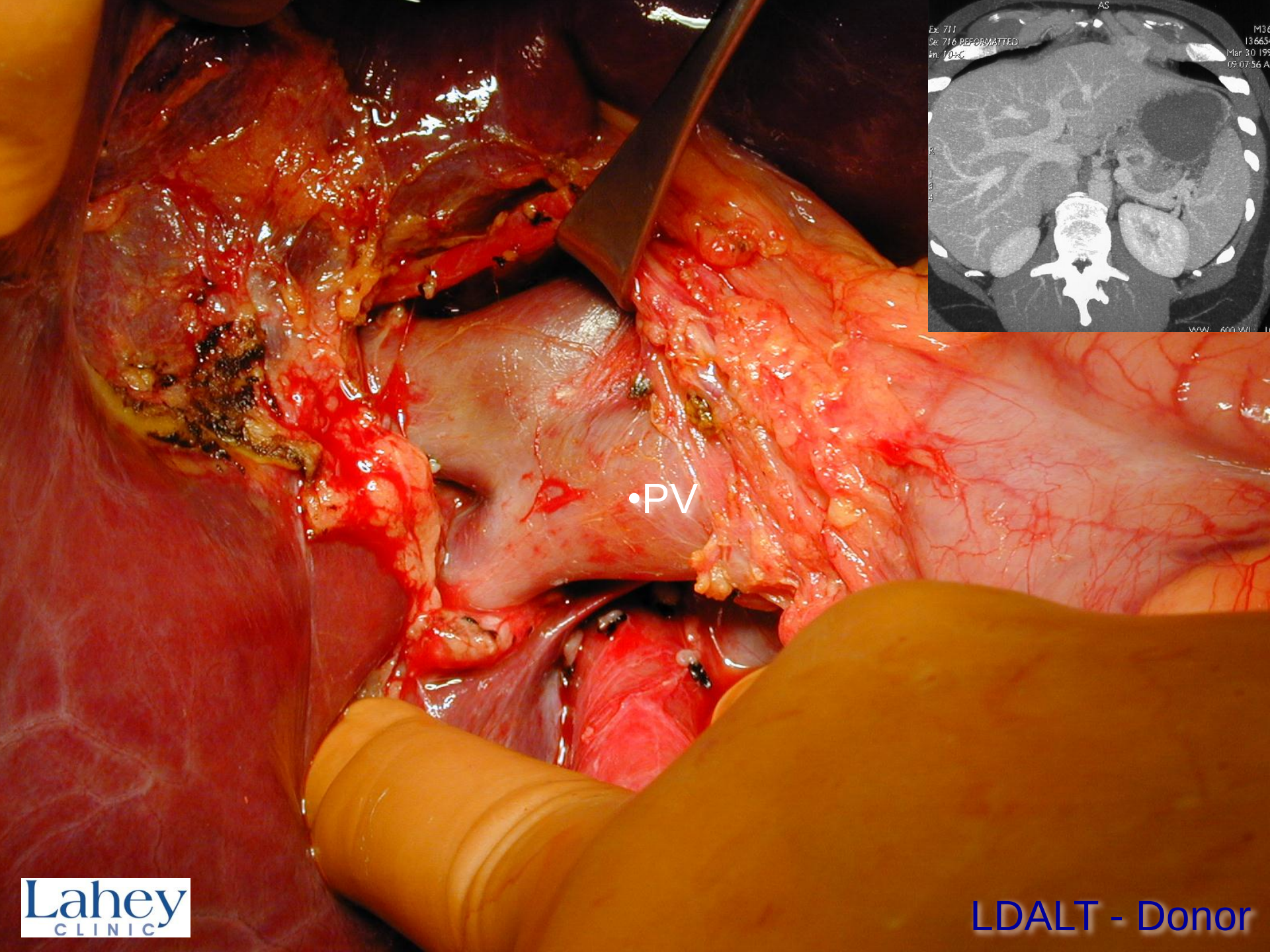
•PV
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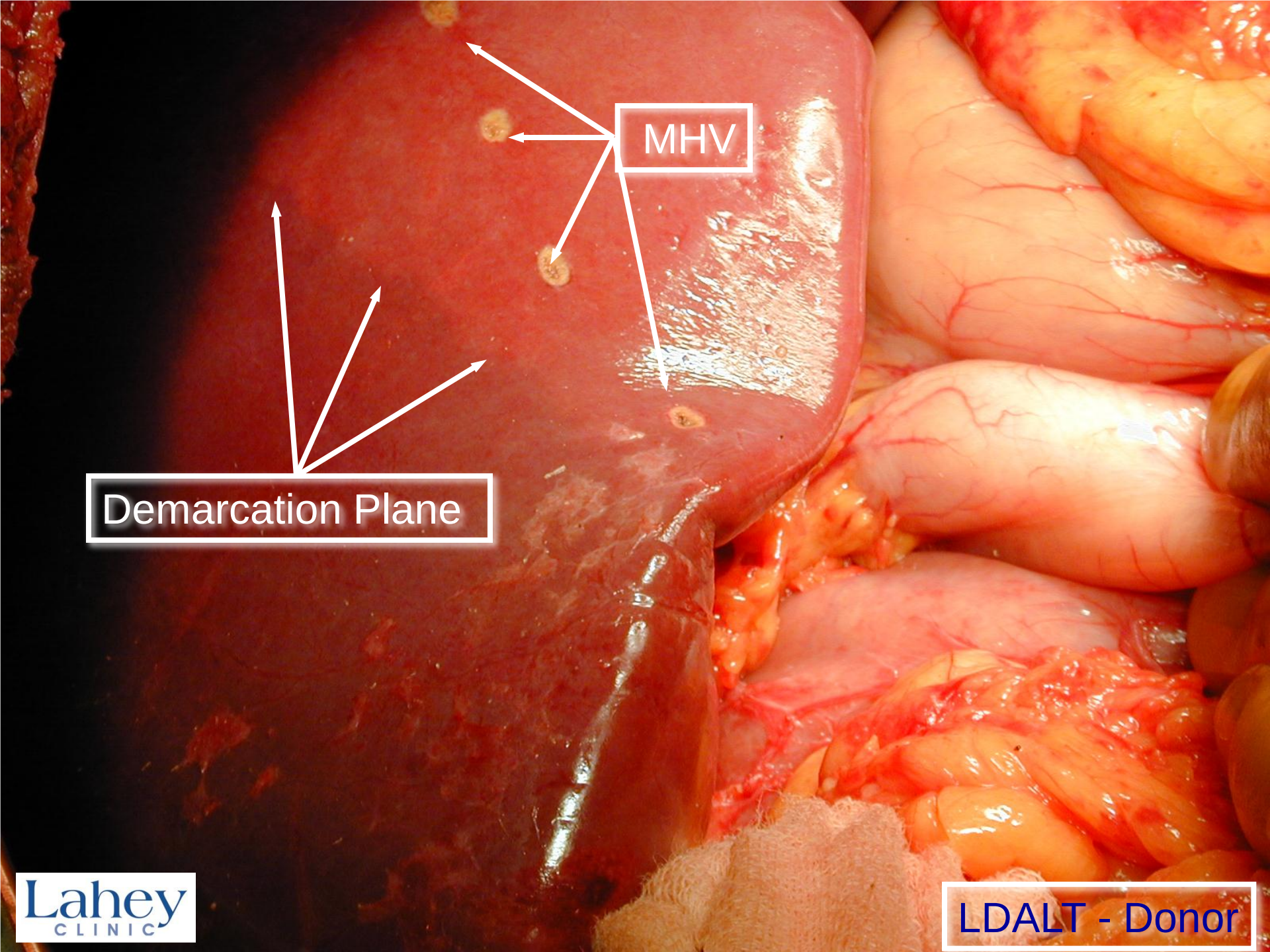
LDALT - Donor



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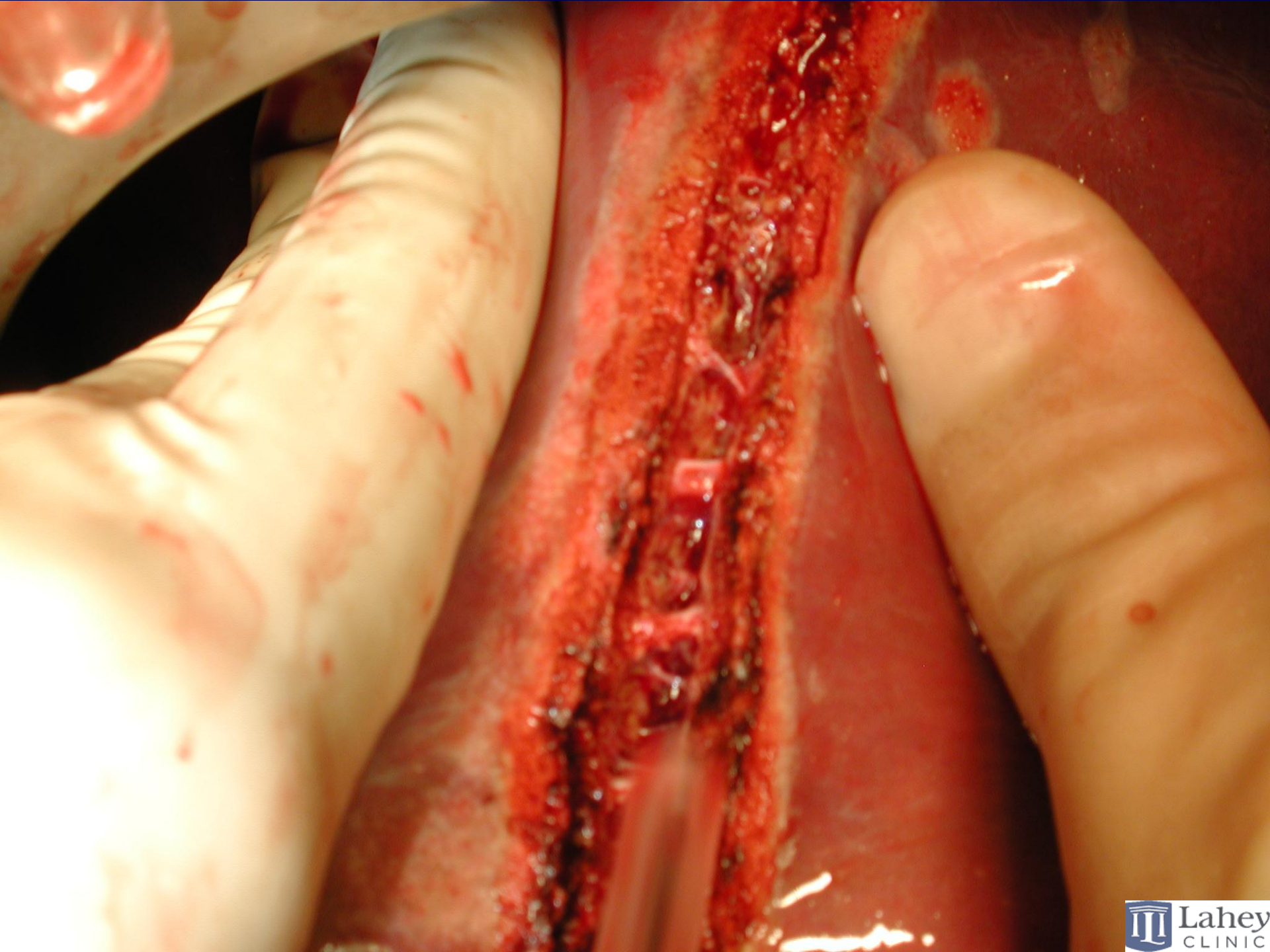

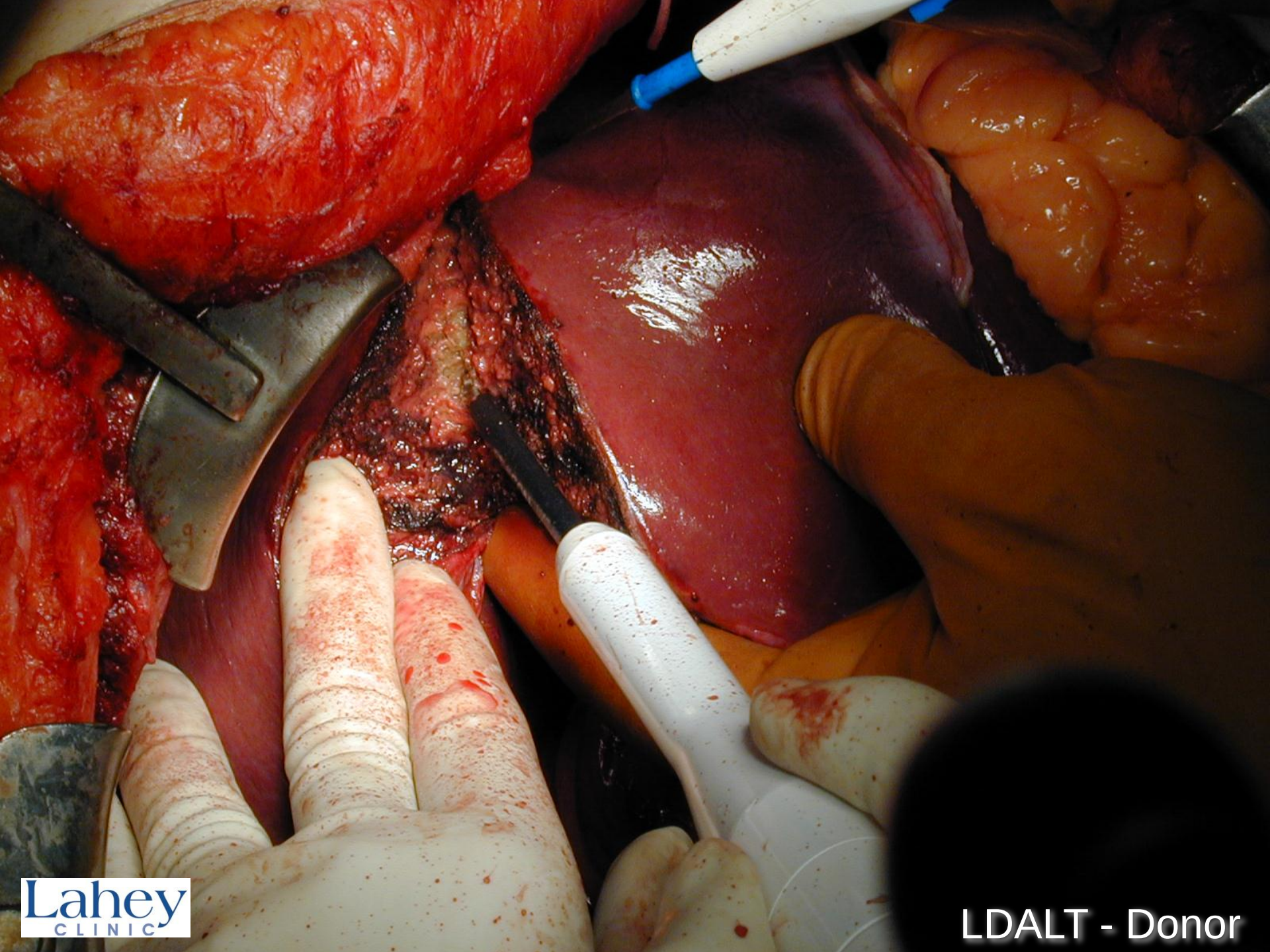
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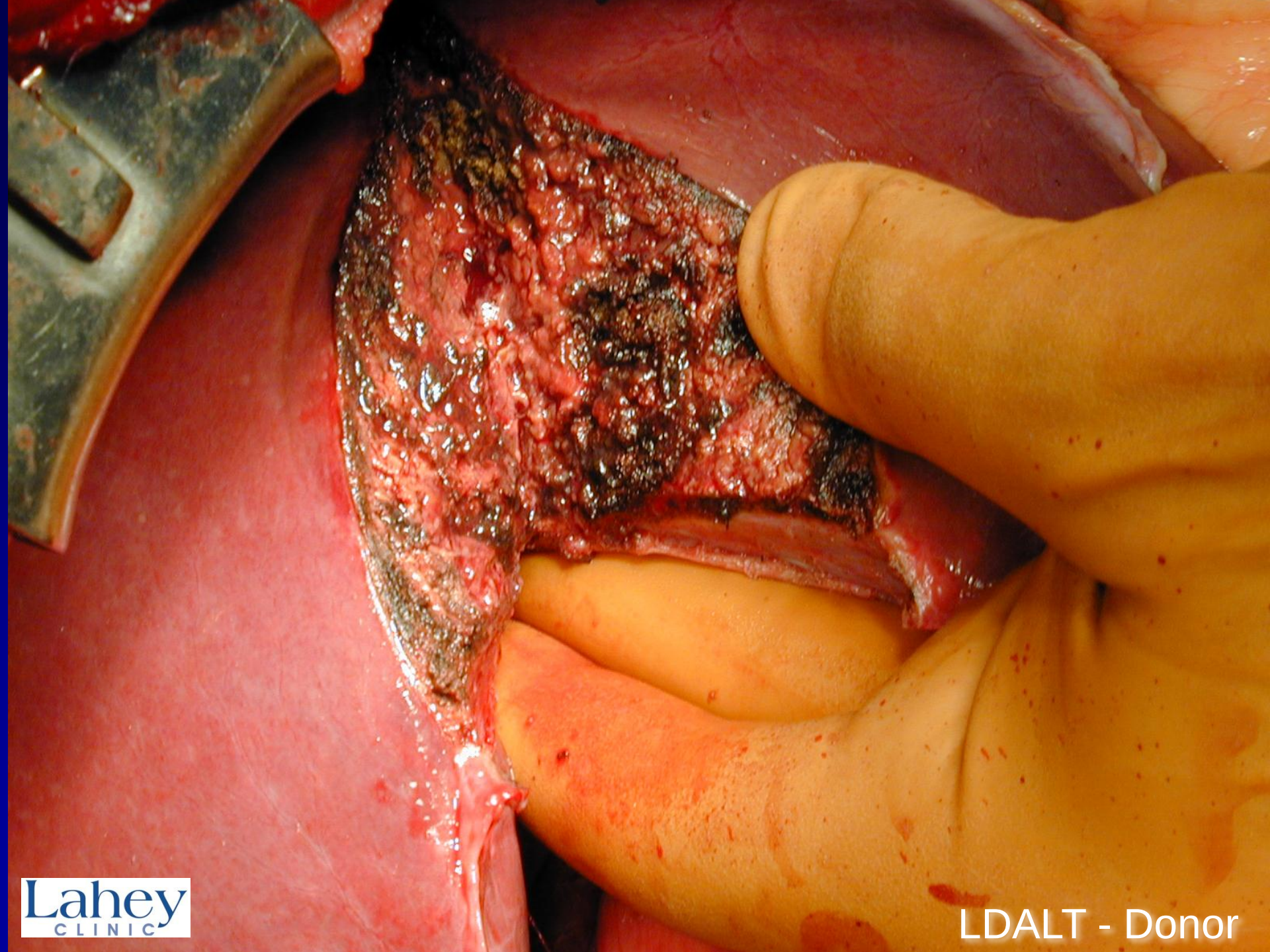
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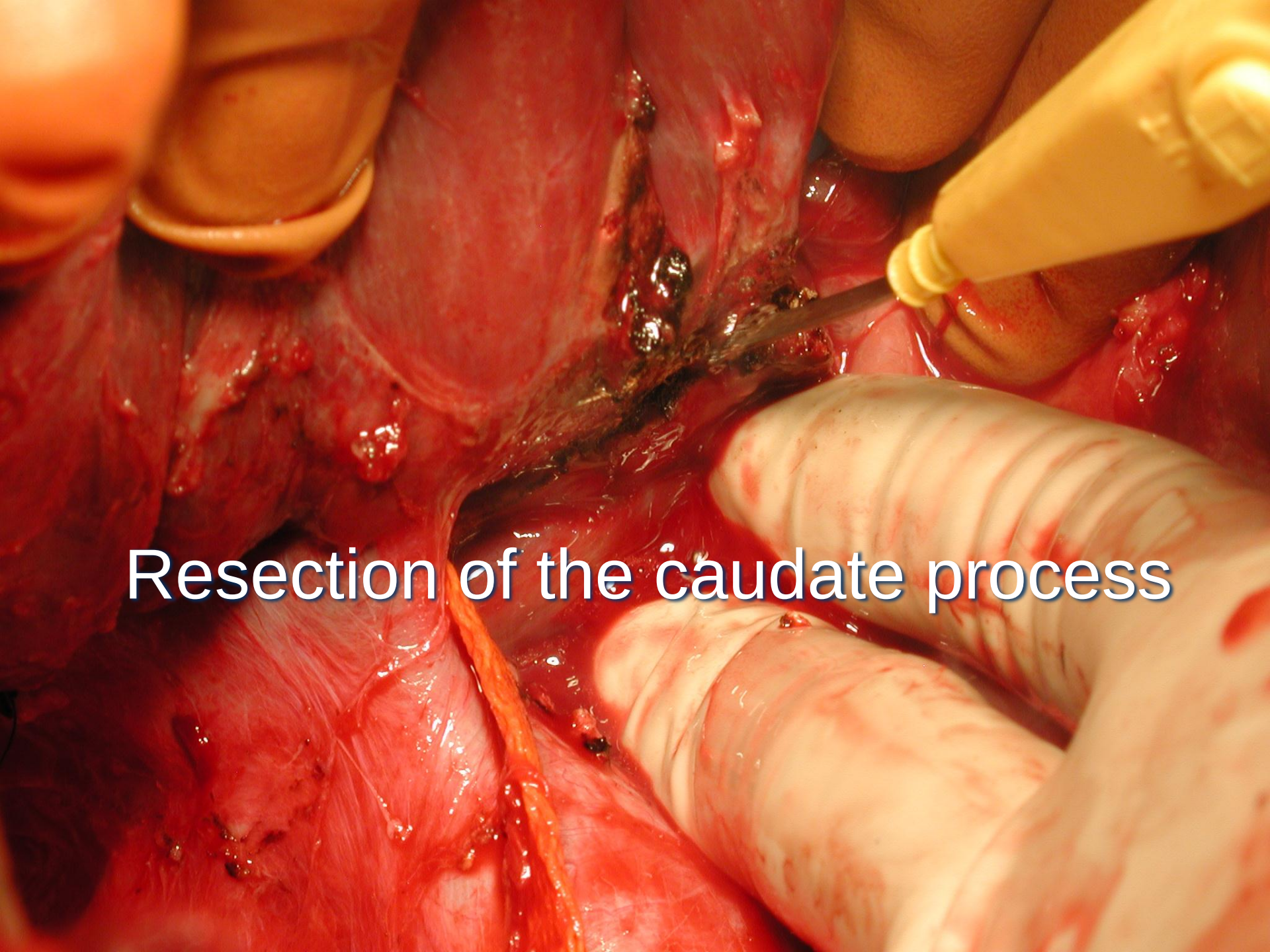
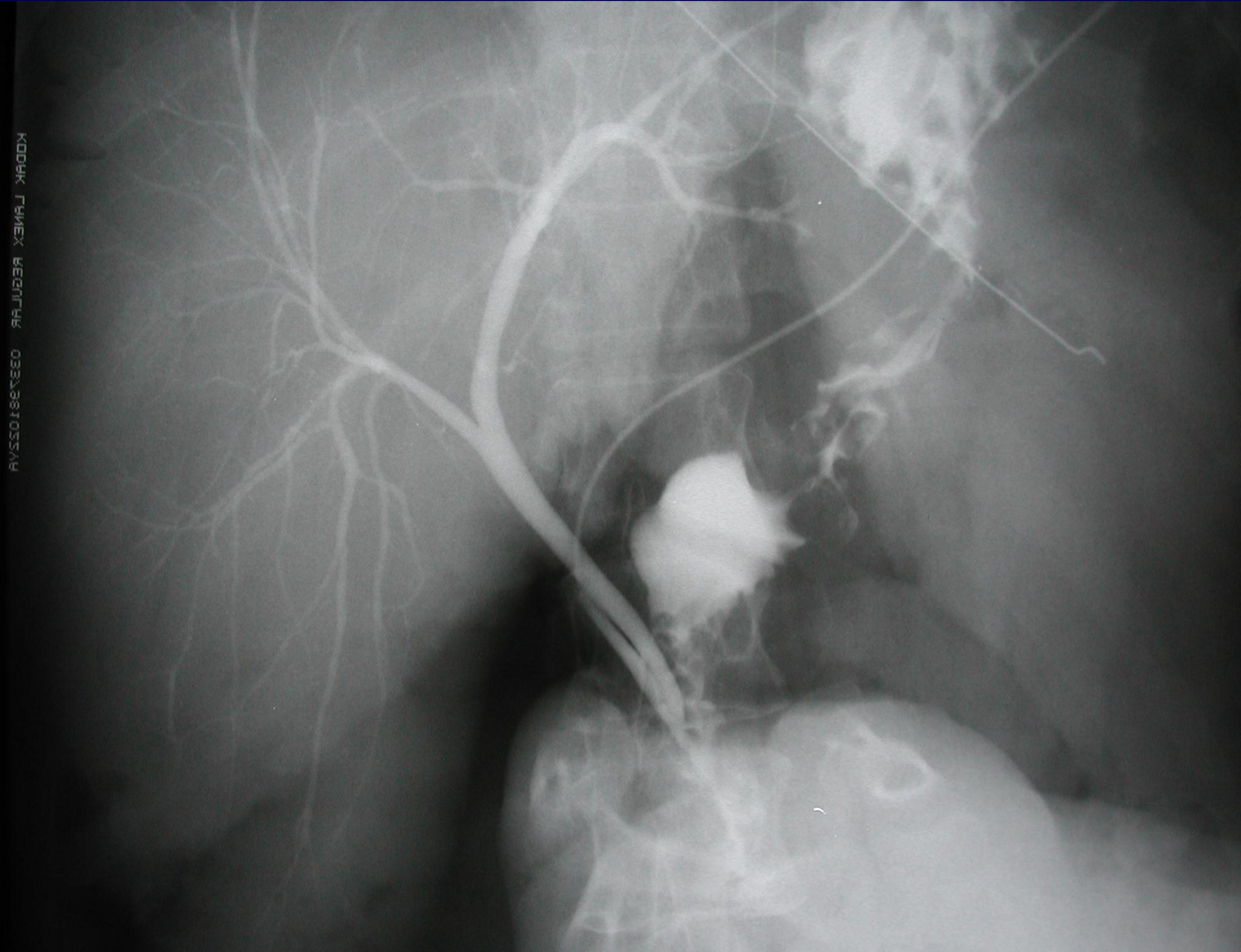
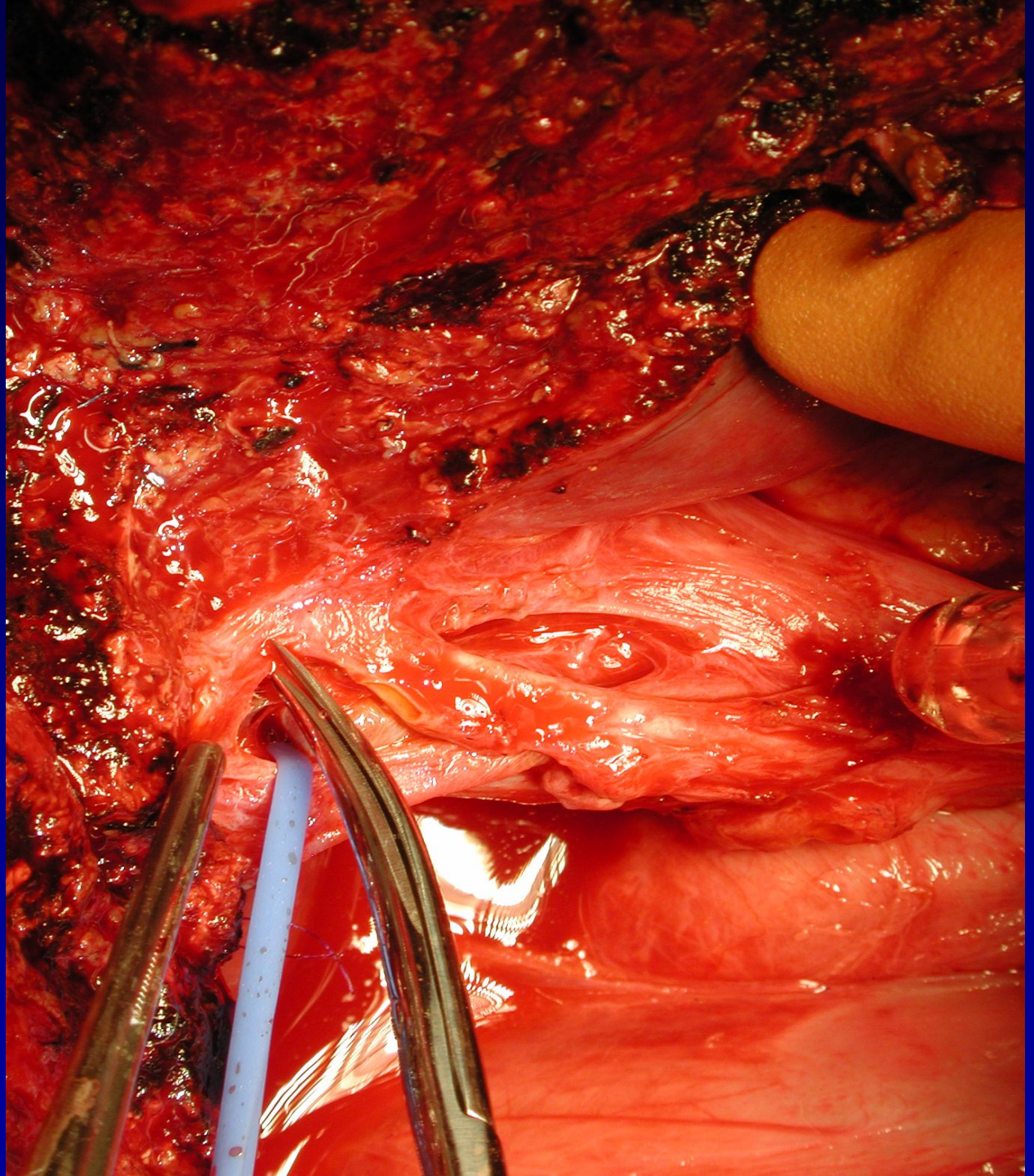
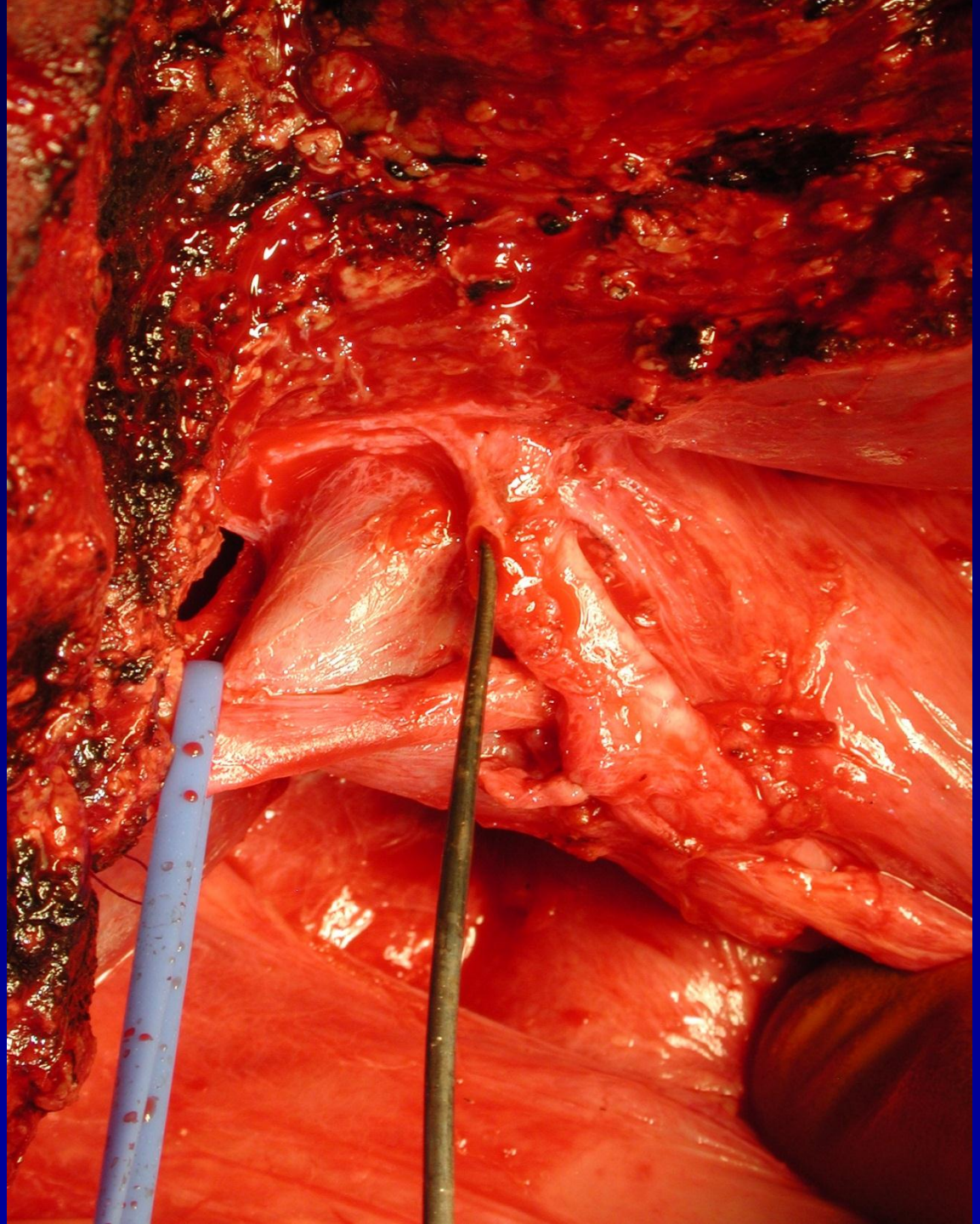
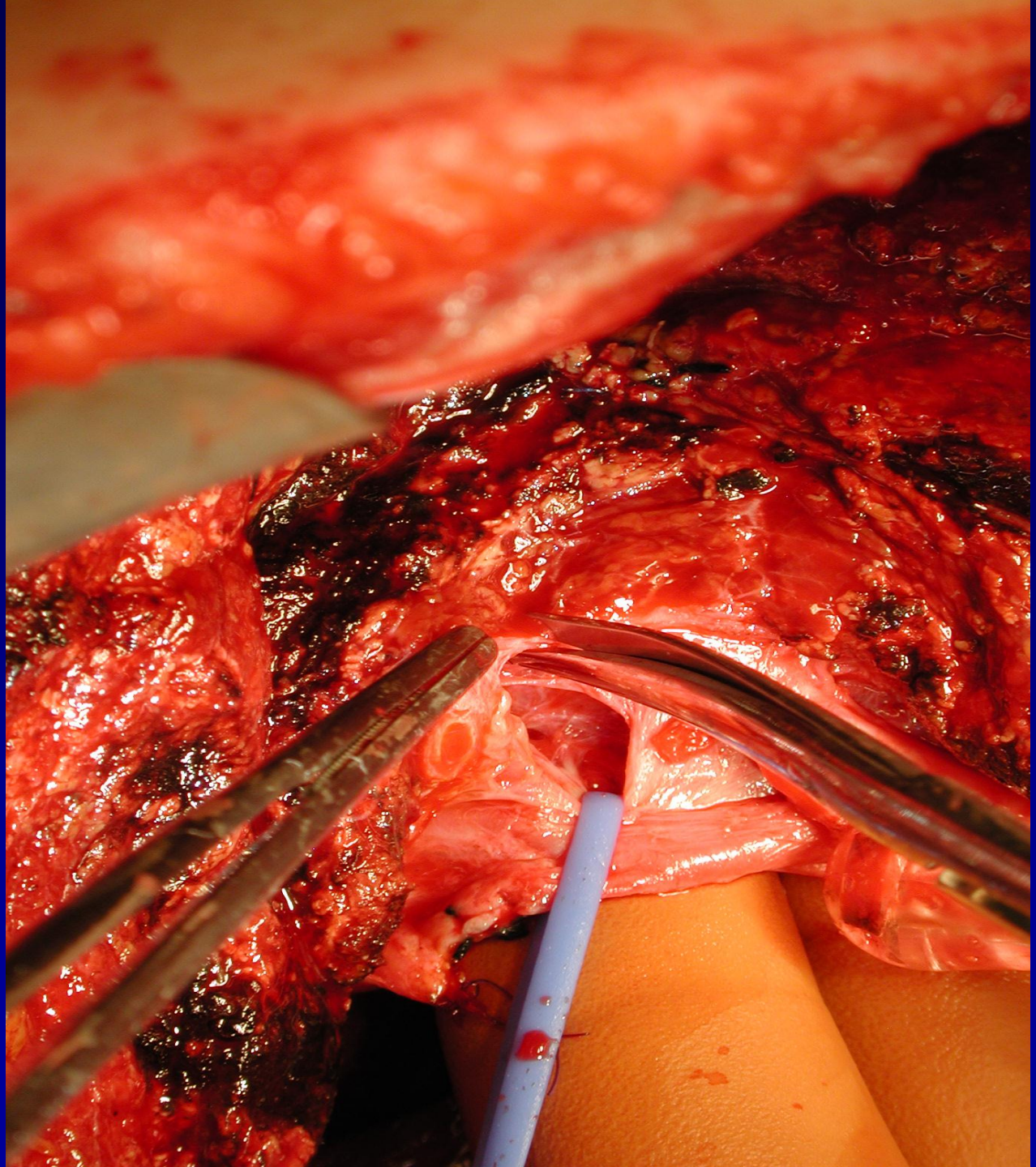
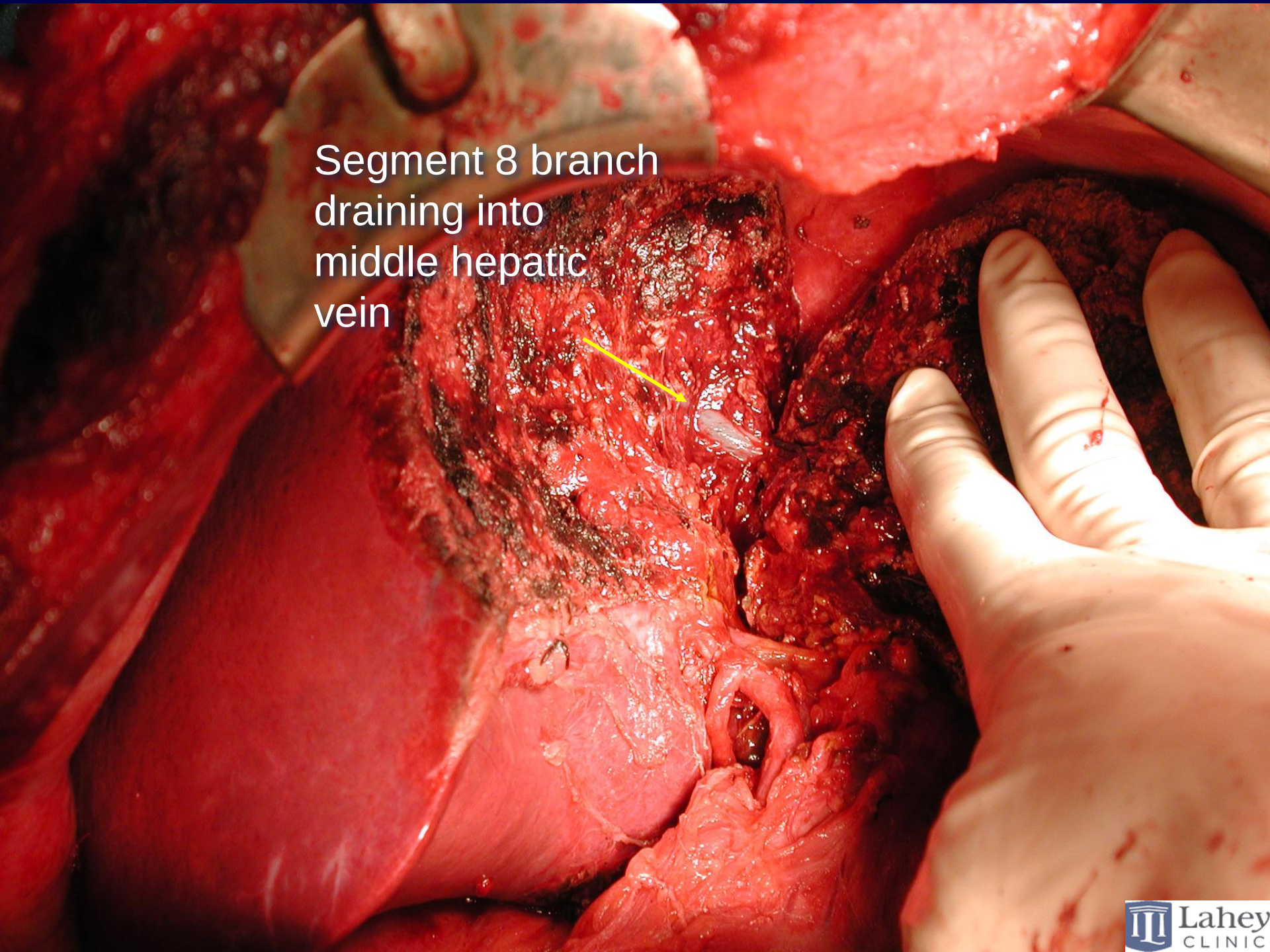

Resection of the caudate process

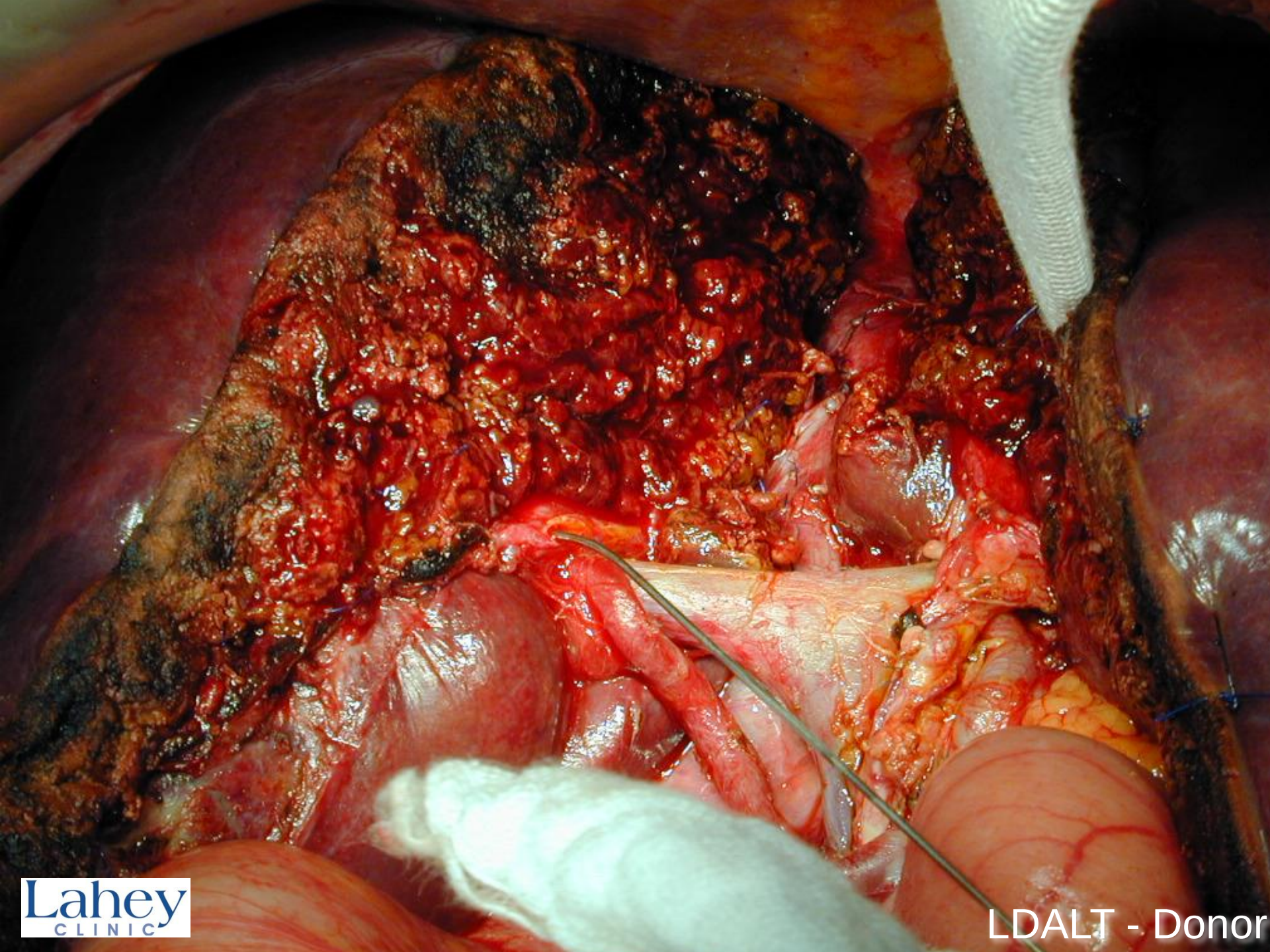









Segment 8 branch draining into middle hepatic vein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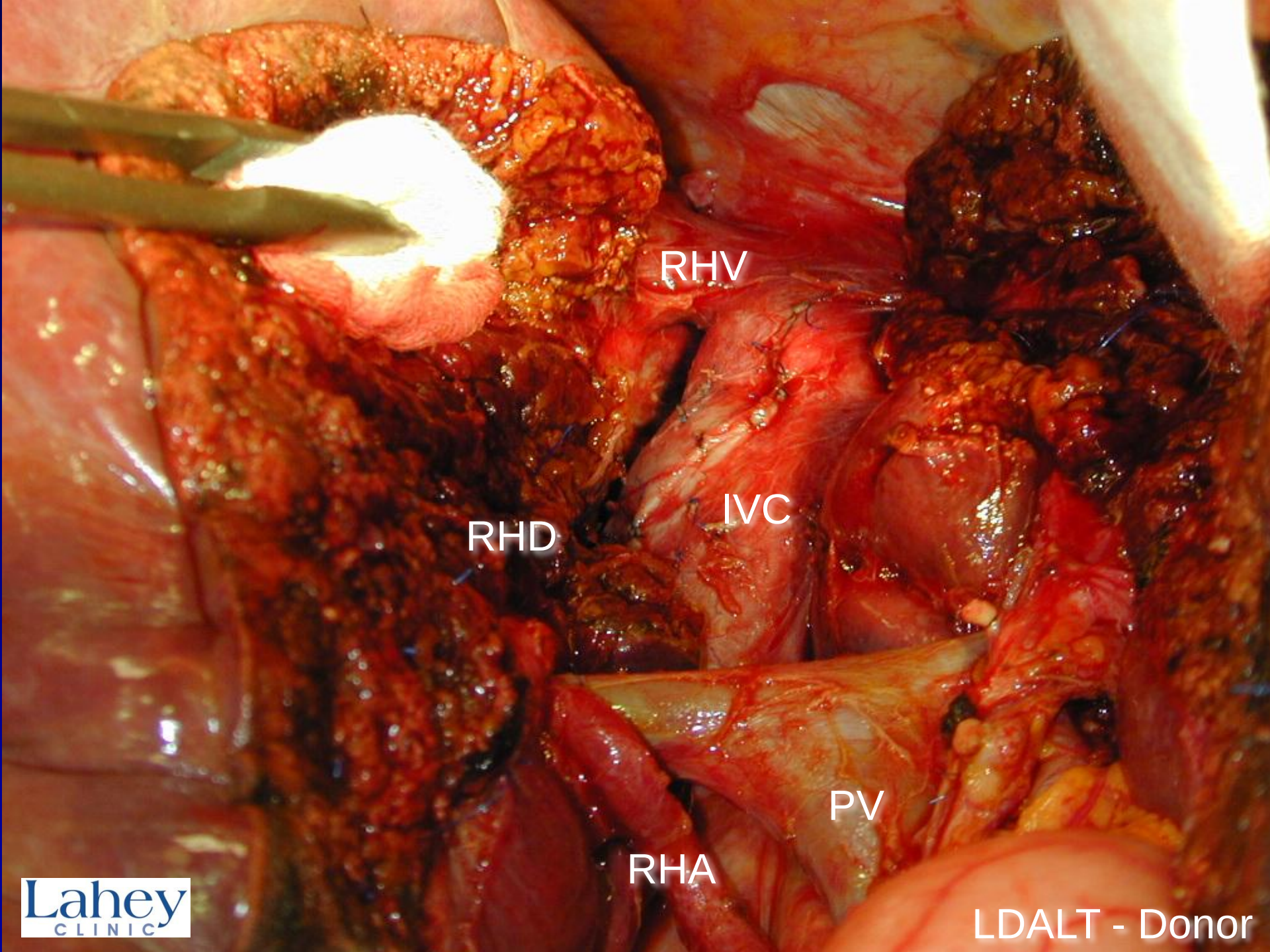
RHV
IVC
RHD
PV
RHA
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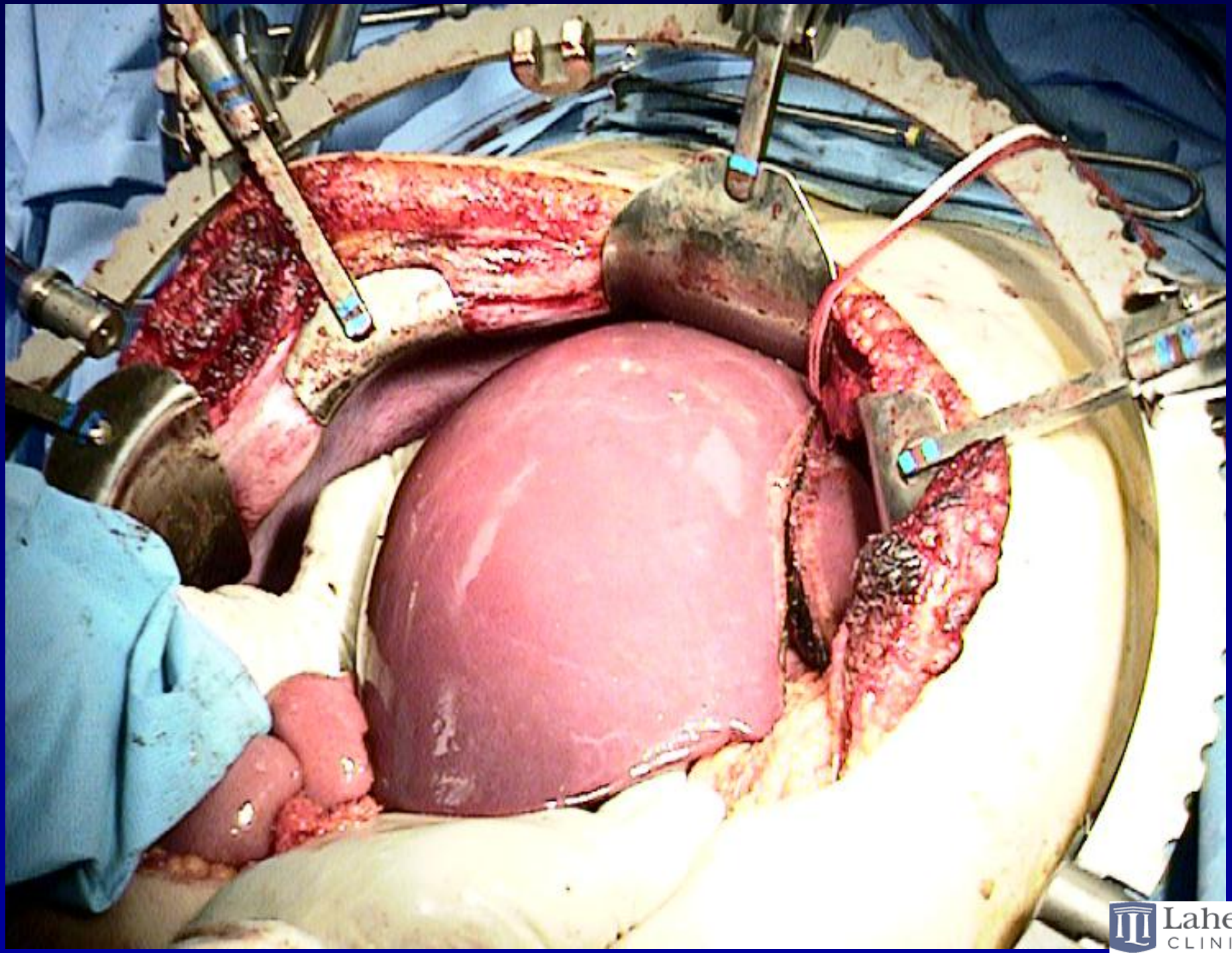
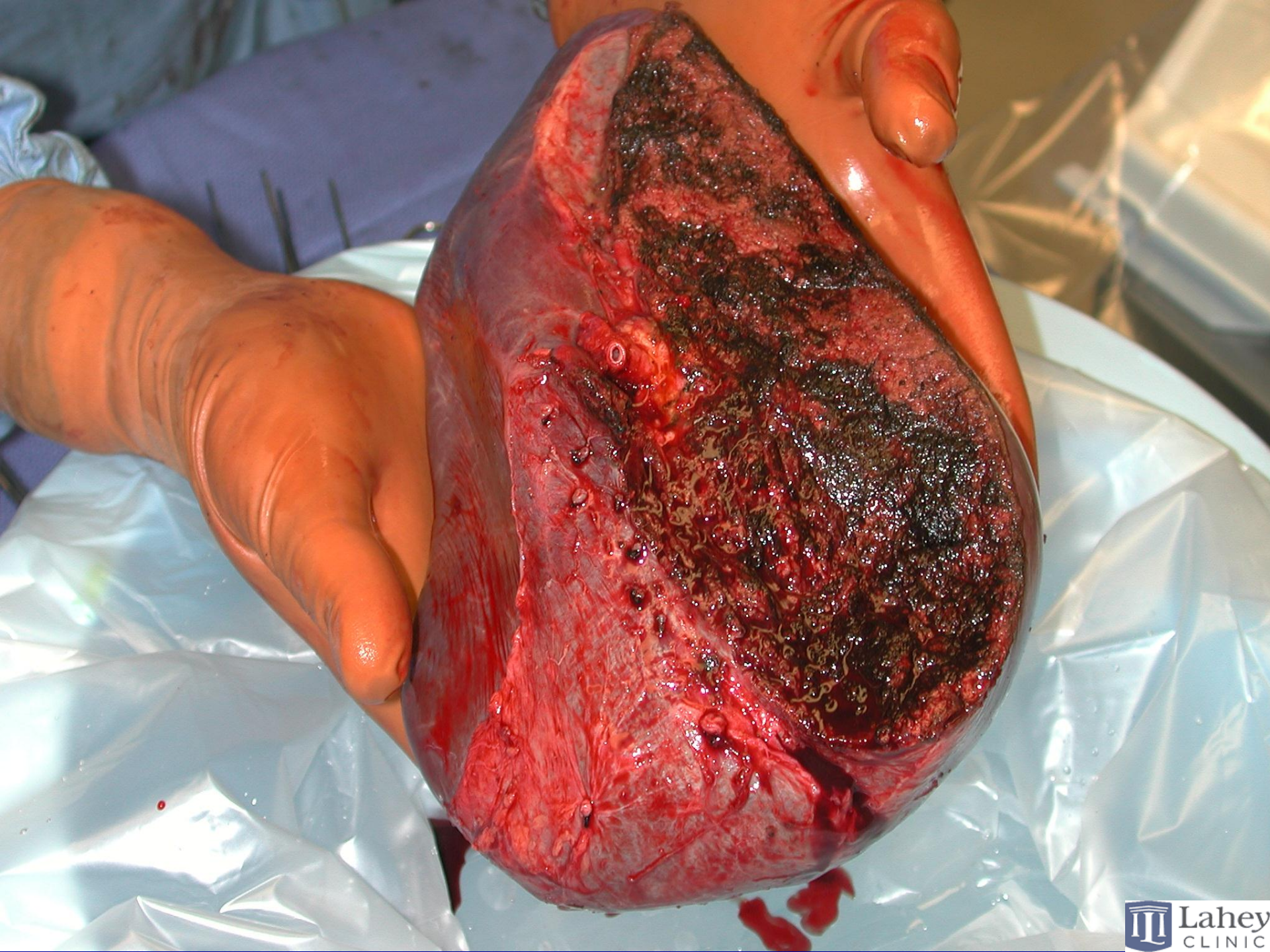
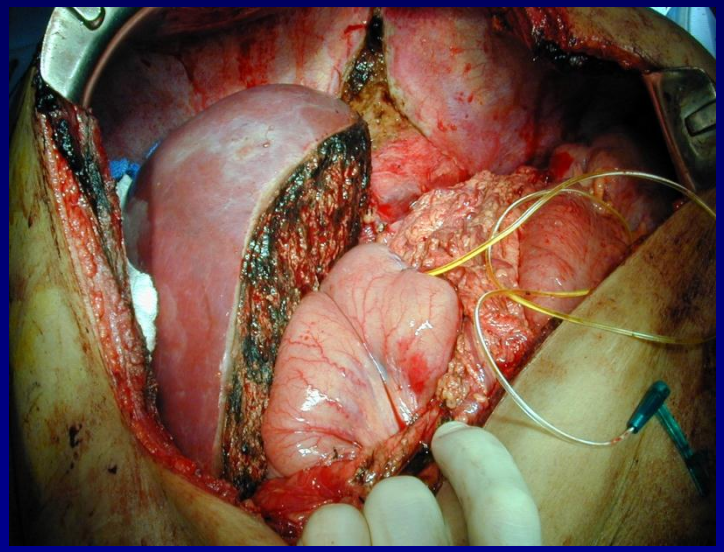
LDALT - Donor





Factors Influencing the Success of Living Donor Adult Liver Transplantation

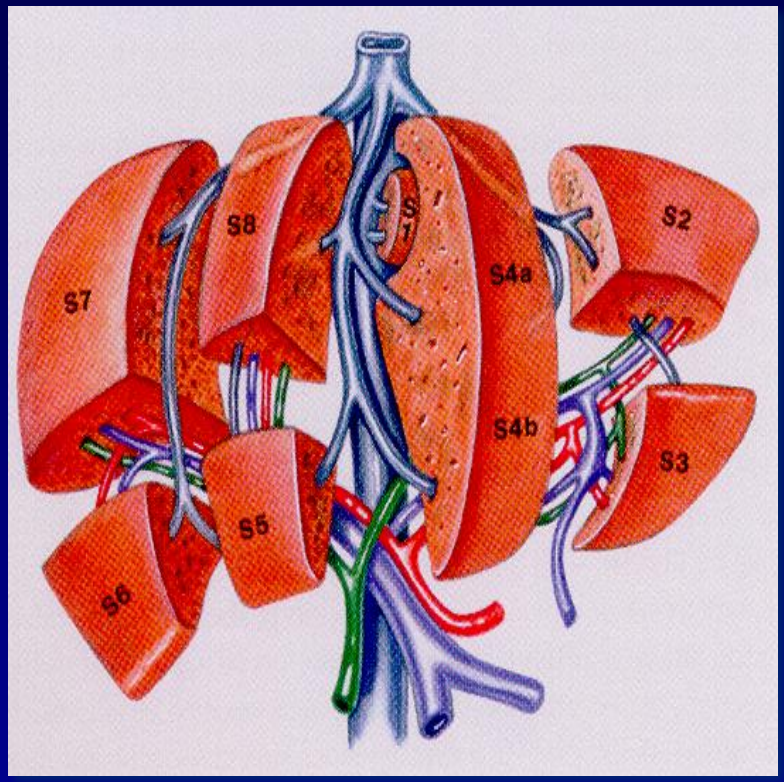
- Program Experience
- Graft Size
  - SFSS
- Recipient Diagnosis
- Recipient Disease Severity
- Operative Techniques



“Small-for-Size” Syndrome

Partial liver graft unable to meet the functional demands of the recipient resulting in poor early graft function without evidence of ischemic injury

- **Poor bile production**
- **Prolonged cholestasis**
- **Significant ascites**
- **Coagulopathy**



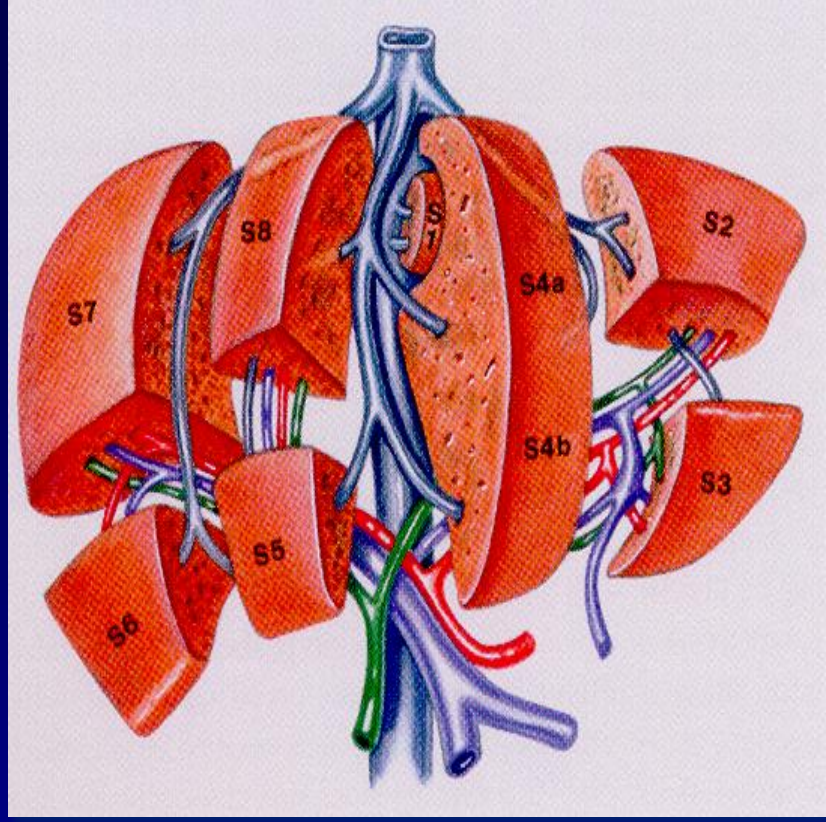
SFSS

Biochemical Profile:

- Elevated TB (conjugated)
- Mild to moderate elevation of transaminases
- Prolonged PT

•Histological Features:

- Cholestasis with bile plugs
- Areas of regeneration and ischemia with patchy necrosis



In the context of LT, ~ 50% of recipients with SFSS will die of sepsis within 4-6 weeks

Impact of graft size mismatching on graft prognosis in liver transplantation from living donors. Kiuchi T et al. Transplantation. 1999; 67:321-327

- 276 LDLT recipients
- "Extra small" grafts: GRWR < 0.8%
- "Small" grafts: GRWR < 1% or < 40% SLV
  - Survival in recipients of grafts <0.8% was less than 50% at one year
  - Death was invariably from sepsis in association with liver dysfunction.

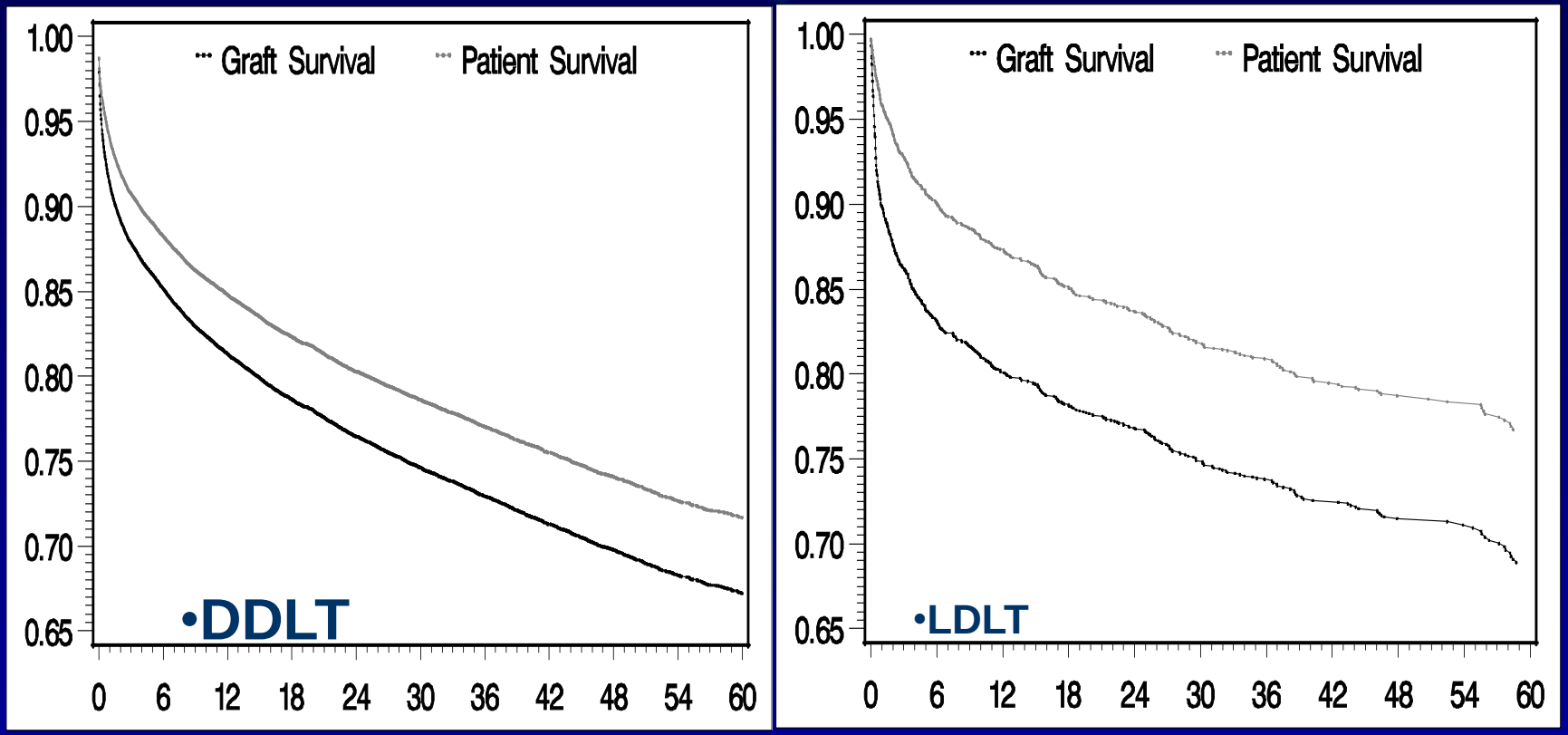
For the first time it was possible for surgeons to equate the weight of a partial liver graft of excellent quality with subsequent function.

Critical graft size in adult-to-adult living donor liver transplantation: Impact of the recipient's disease

•Ben-Haim M et al. Liver Transplantation. 2001; 7:948-953.

- 40 LDALT (10 Left lobe, 30 Right lobe)
- Small grafts: GRWR ≤ 0.85%
- GRWR as low as 0.6% can be used in pts with normal liver function (Child's A)
- Child's B and C: graft survival was 74% vs. 33% in recipients of large vs. small grafts respectively
  - Graft function and survival are influenced by both graft size and pretransplantation disease severity
  - GRWR > 0.85% needed in cirrhotic patients to avoid "small-for-size" syndrome.

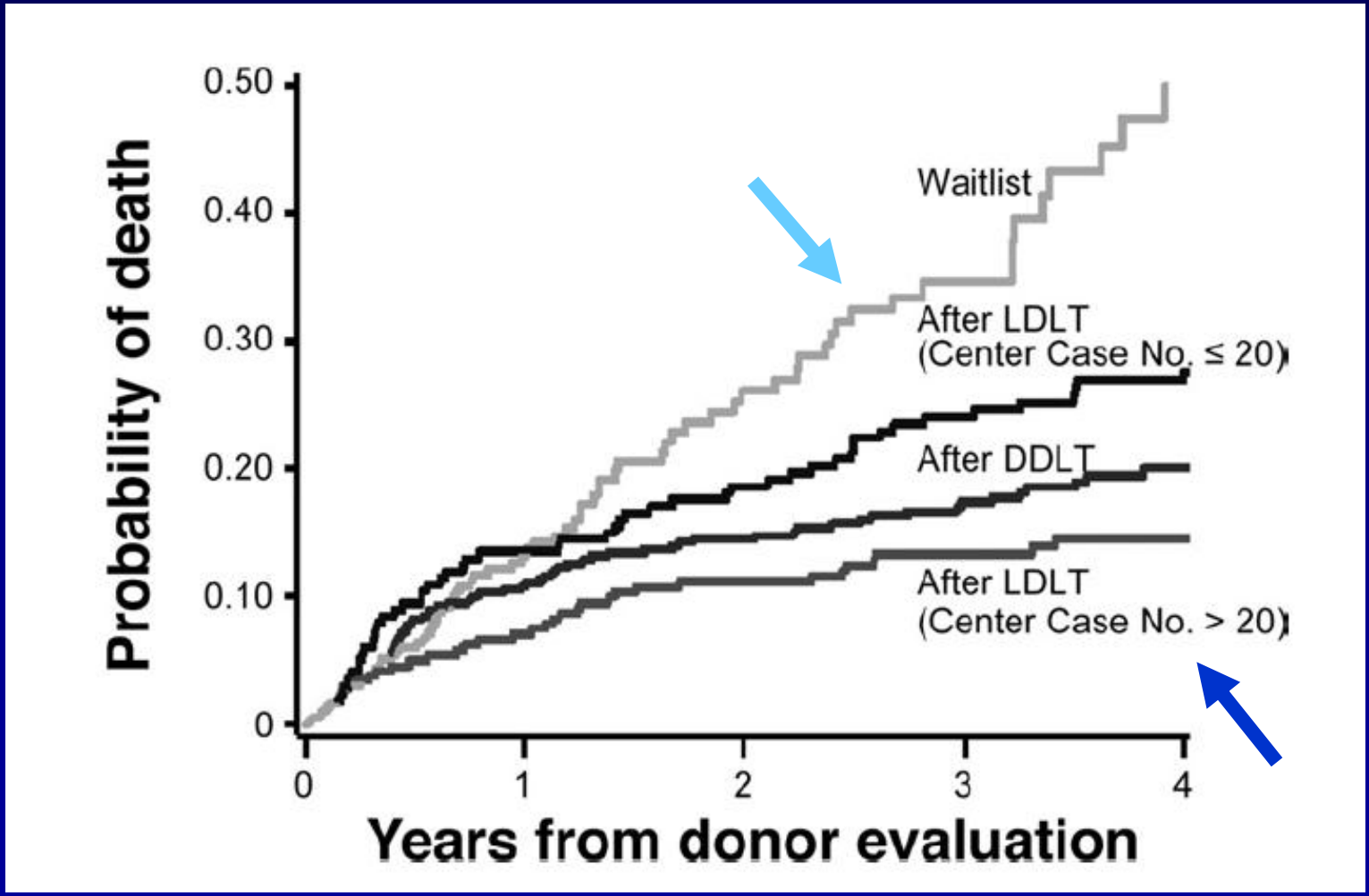
Adjusted Patient and Graft Survival of Adult Liver Recipients by Type of Transplant



Pt Survival: DDLT: 93%, 87%, 79%, 73% vs. LDLT: 96%, 92%, 83%,77%

Pomfret et al: AJT 2007; 7: 1376-1389

Cumulative Risk of Death After Initial LD Evaluation for Patients Undergoing LDLT vs. DDLT Stratified by Center Experience



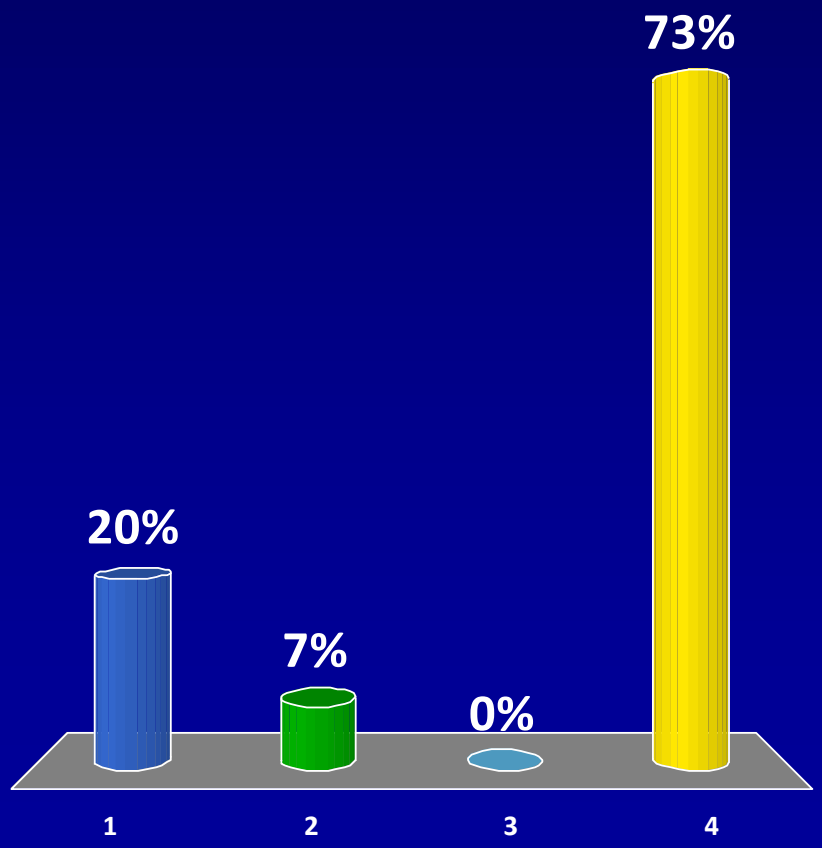
Adjusted for age, MELD score and HCC

Program Requirements for a Successful Split/Living Donor Program

1. Adequate training in major liver resection surgery
2. “Field Strength”
3. Institutional Support/Infrastructure (QAPI)
4. LD: Independent Donor Advocate
5. Obsessive Attention to Detail
6. Disaster Plan

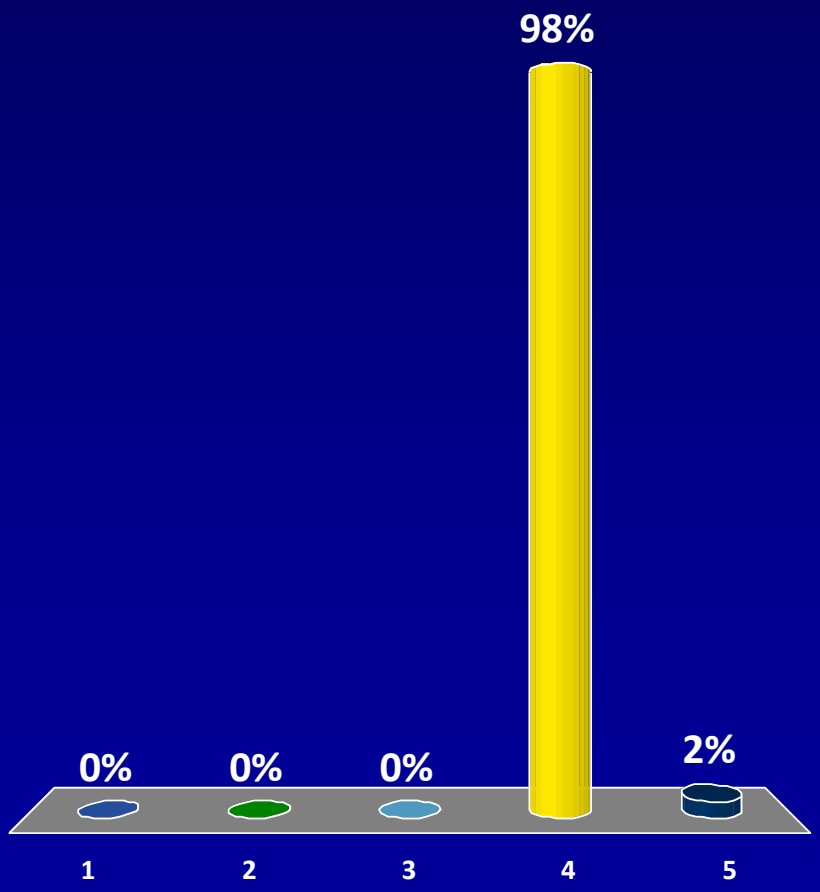
Question 1: Post-transplant outcomes associated with classic (LLS/ERL) splits are?

1. Inferior to whole liver grafts for both the LLS and Extended Right Lobe
2. Inferior to whole liver grafts for the LLS but not the Extended Right Lobe
3. Inferior to whole liver grafts for the ERL but not the LLS
4. Equal to whole liver grafts for both LLS and ERL



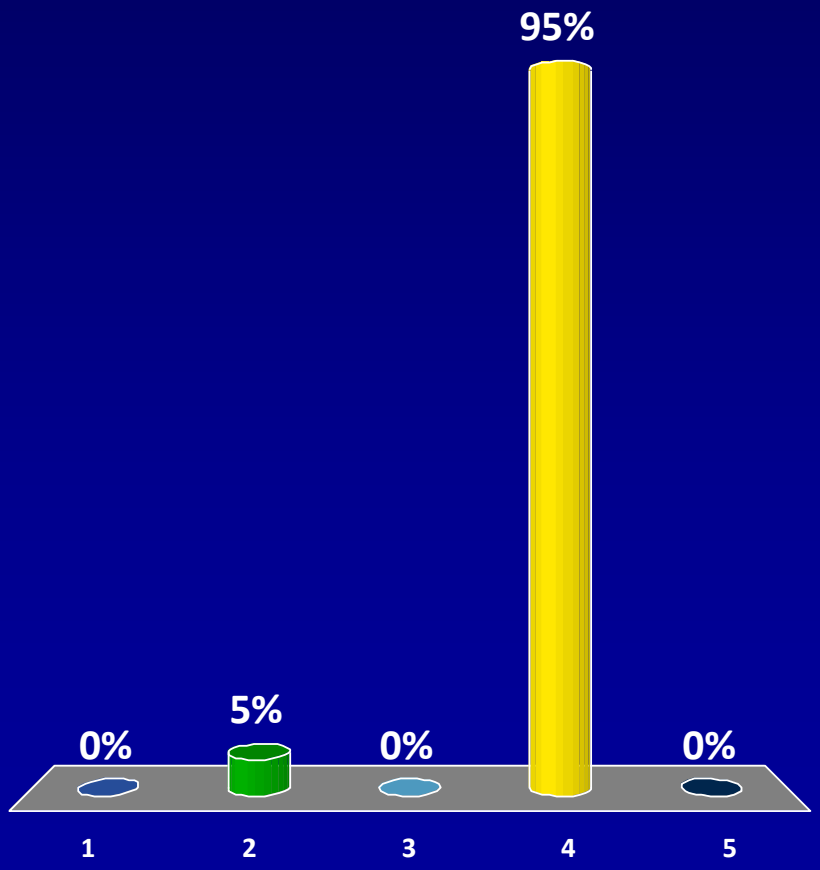
Question 2: The following are required components for a living donor liver program?

1. Independent donor advocate
2. MRI or CT imaging of the donor liver for volume, vascular and biliary anatomy
3. OPTN/UNOS certification of the living donor surgeons
4. All of the above
5. a and c only



Question 3: Donor morbidity:

1. Associated with the extent of donor hepatectomy
2. Statistically decreases with program experience
3. Is approximately ~38% for right lobe donors and ~10% for left lobe donors
4. All of the above
5. a and c only



Factors Influencing the Success of Living Donor Adult Liver Transplantation include:

1. Program experience > 20
2. Graft size > 0.8%
3. Recipient diagnosis and disease severity
4. All of the above
5. None of the above