state of the art in
ADVANCED HEART FAILURE
CLINICAL PRACTICE AND ORGANIZATIONAL MODELS
Venue · University Hospital A Coruña

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Long-term MCS
New Surgical Approaches

Steven Tsui
Papworth Hospital, Cambridge, UK.

Long-Term MCS

~~New~~ Surgical Approaches

Alternative

1. Why do it differently?
2. Minimal Access vs. Minimally Invasive?
3. How I do it?
4. Outcomes

Why do it differently?

- Known damaging effects of CPB on:
  - PVR
  - Coagulation
  - RV function
- For cardiogenic shock (INTERMACS I), routinely implant temporary VAD off-pump
- Protocol for on-pump LVAD implantation to:
  - Minimise duration
  - Mitigate against damaging effects

My First Less Invasive Case:
June 2012

- Age: 62 y.o Male
- Diagnosis: DCM
- Support:
  - Dopamine 5 mcg/kg/min
  - Enoximone 5 mcg/kg/min
  - Others IABP + CVVH
- Haemodynamics:
  - CVP 14 mmHg - PCWP 28 mmHg
  - CO 3.1 L/min - CI 1.5 L/min/m^2
  - PVR 4.1 WU - SvO_2 41%

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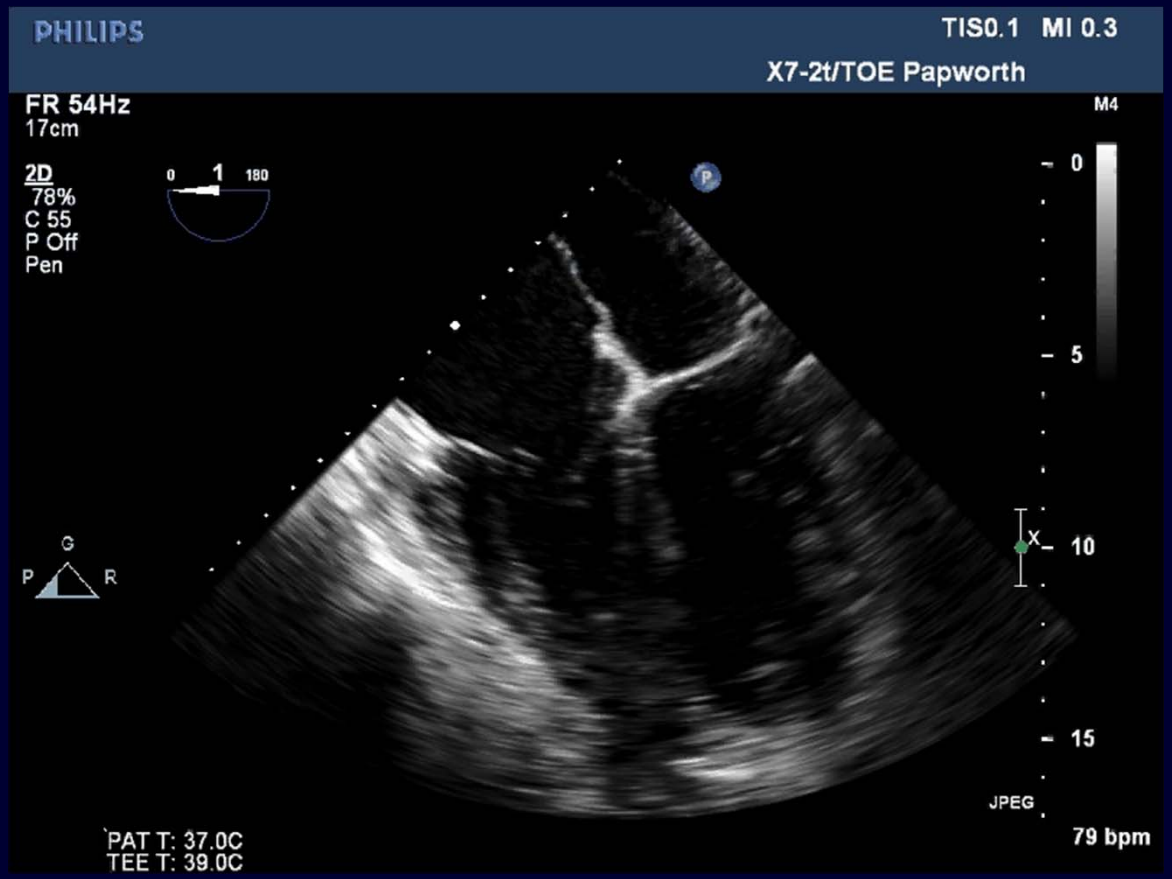
My First Less Invasive Case:

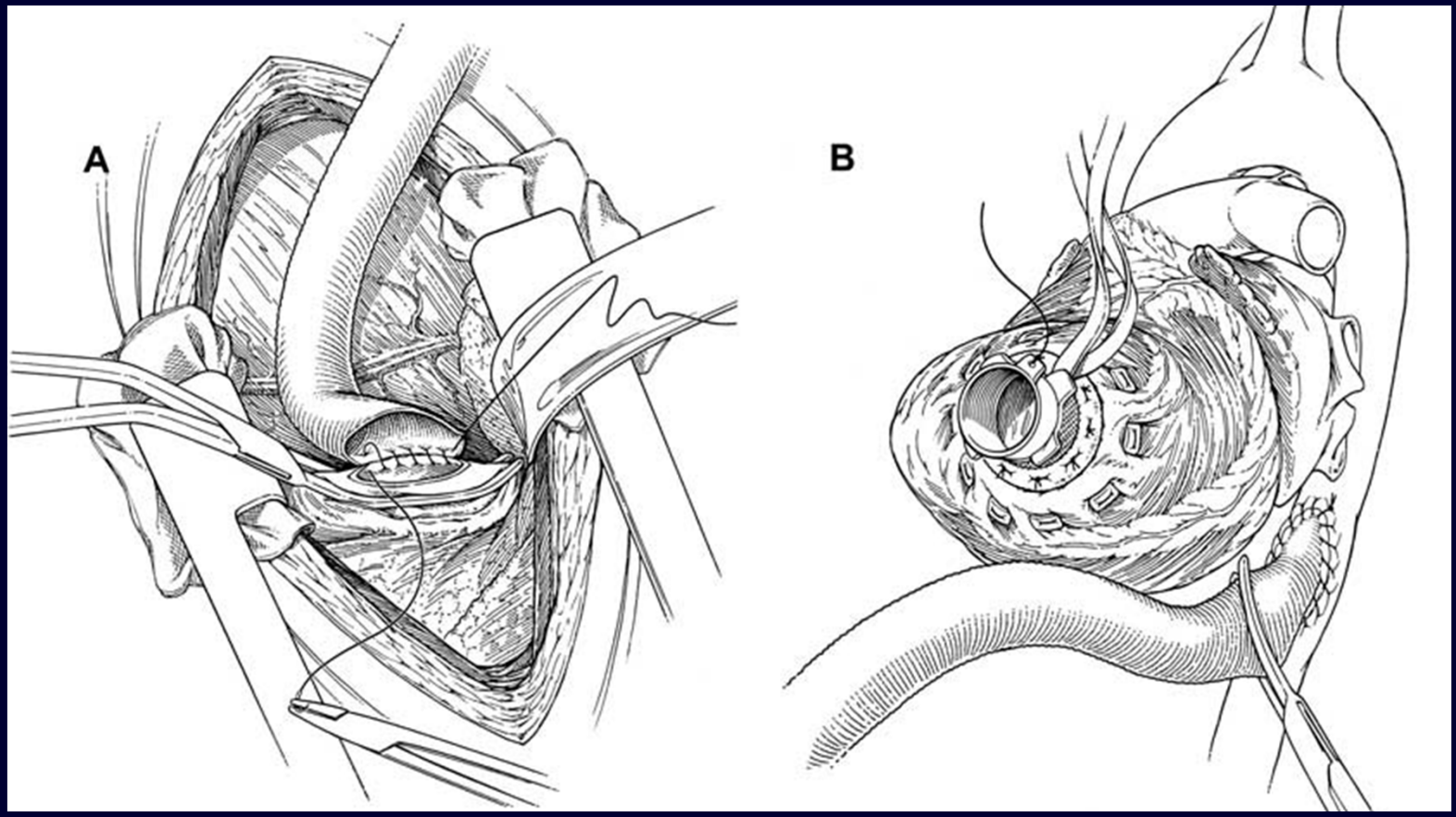
June 2012



My First Less Invasive Case:
June 2012

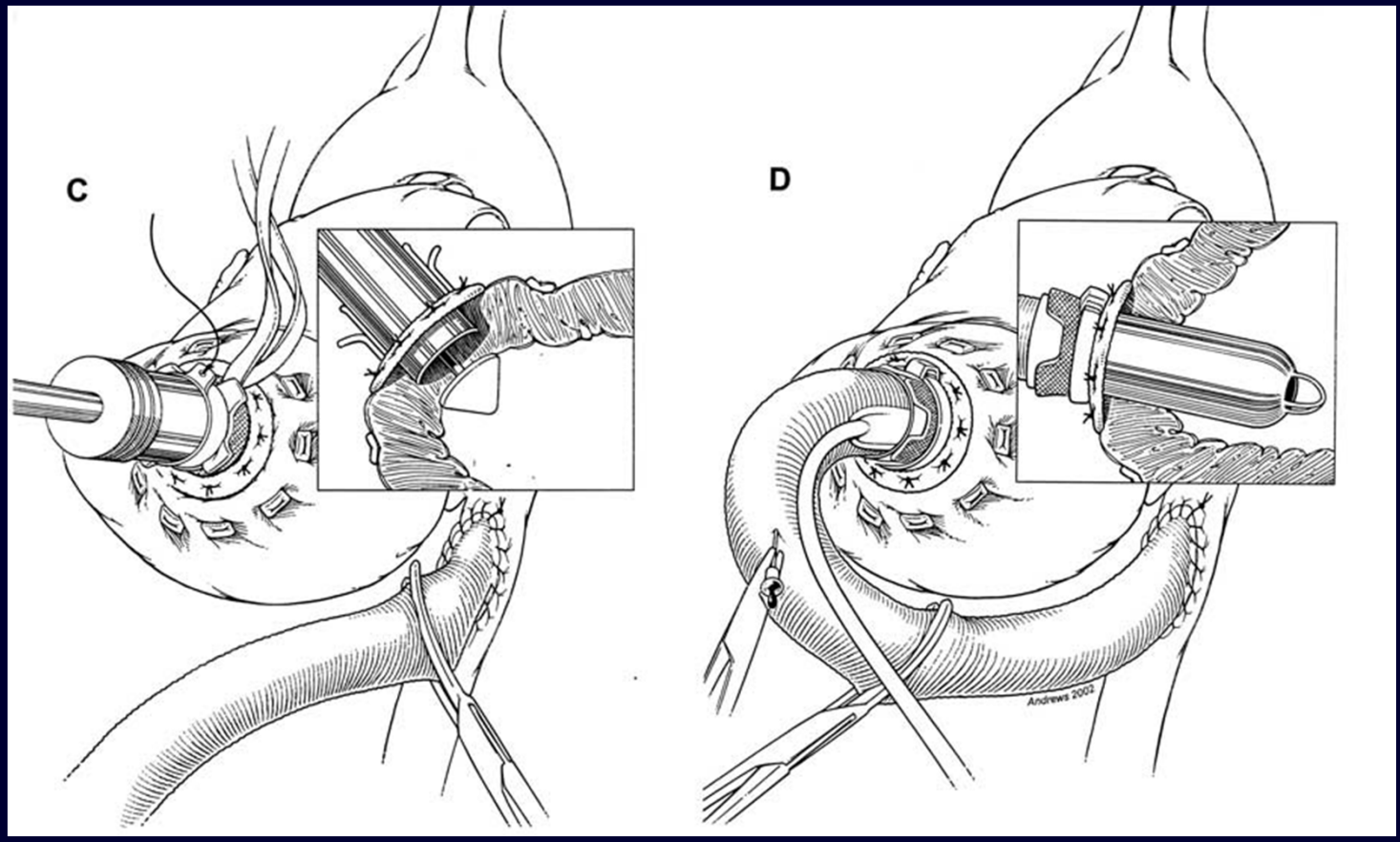
- End organ function
  - Creatinine — 185 μmol/L (NR 35-125)
  - Bilirubin — 52 μmol/L (NR <17)
  - INR — 1.4
  - Falling platelet count — from 250 → <100
- INTERMACS: — Profile II
- Other problem: — ***Heparin induced thrombocytopenia***

Jarvik 2000 Implant Off Pump



OH Frazier Ann Thorac Surg 2003:75:1028-30

Jarvik 2000 Implant Off Pump



OH Frazier Ann Thorac Surg 2003:75:1028-30

Advantages of **Off-pump**

- For CABG:
  - Reduce blood-product transfusion
  - Reduce reoperation for perioperative bleeding
  - Reduce acute kidney injury
  - Reduce respiratory complications
- For LVAD implants, potential to avoid:
  - SIRS
  - Fibrinolysis
  - platelet sequestration
  - degradation of coagulation factors

Advantages of **Minimal Access**

- For valve surgery:
  - similar mortality rates
  - decreased post operative bleeding
  - shorter ICU/hospital stay
  - reduce costs
- For LVAD implant
  - Preserves RV geometry
  - Facilitates LVAD explant / HTx

Varying Degrees Of Invasiveness

	Standard					
Full sternotomy	YES					
Intravenous heparin	YES					
Arterial & Venous Cannulation	YES					
CPB	YES					

Varying Degrees Of Invasiveness

	Standard	Thoracotomy On pump				
Full sternotomy	YES	NO				
Intravenous heparin	YES	YES				
Arterial & Venous Cannulation	YES	YES				
CPB	YES	YES				

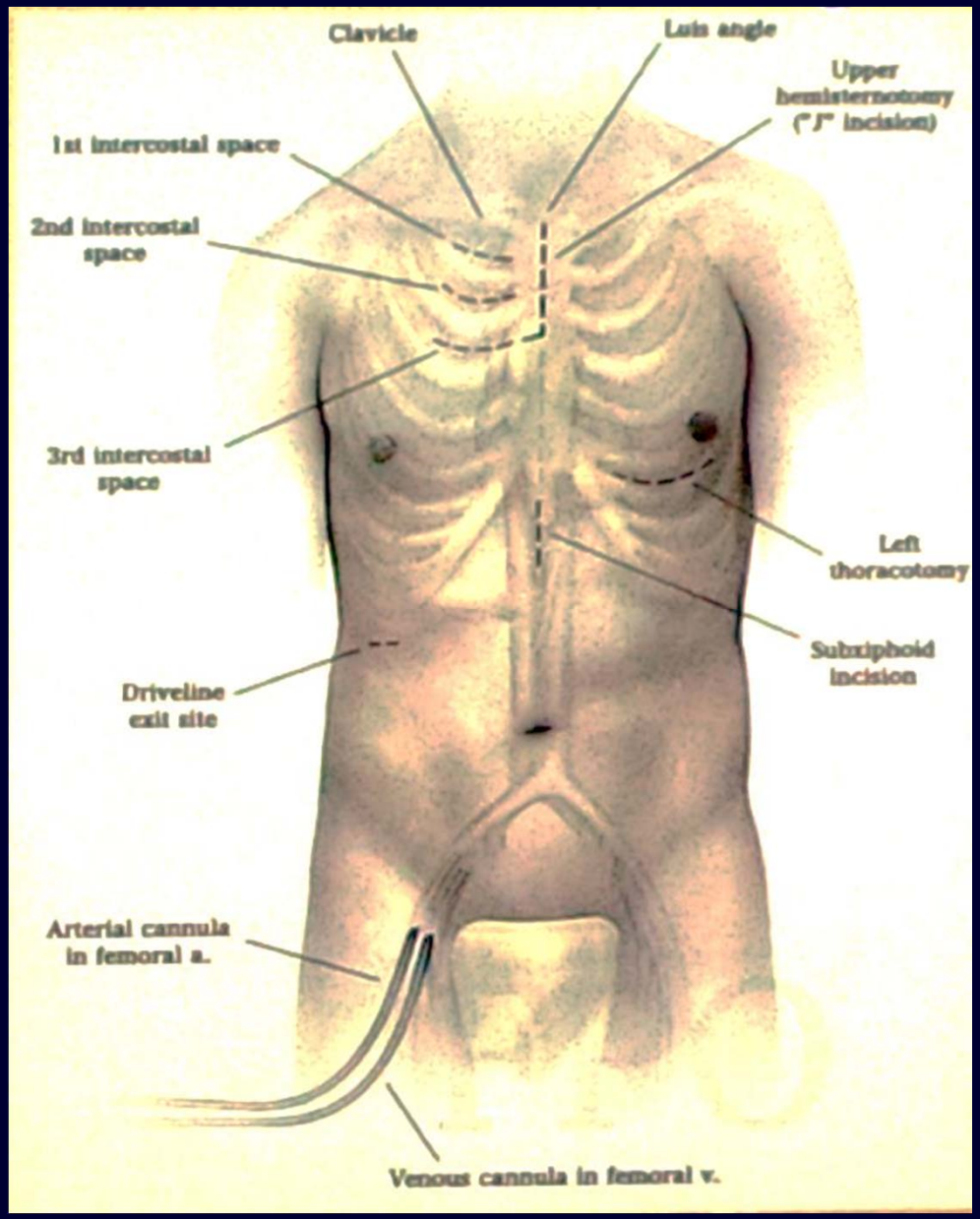
Minimal Access Options

For Inflow

- Thoracotomy
- Subcostal

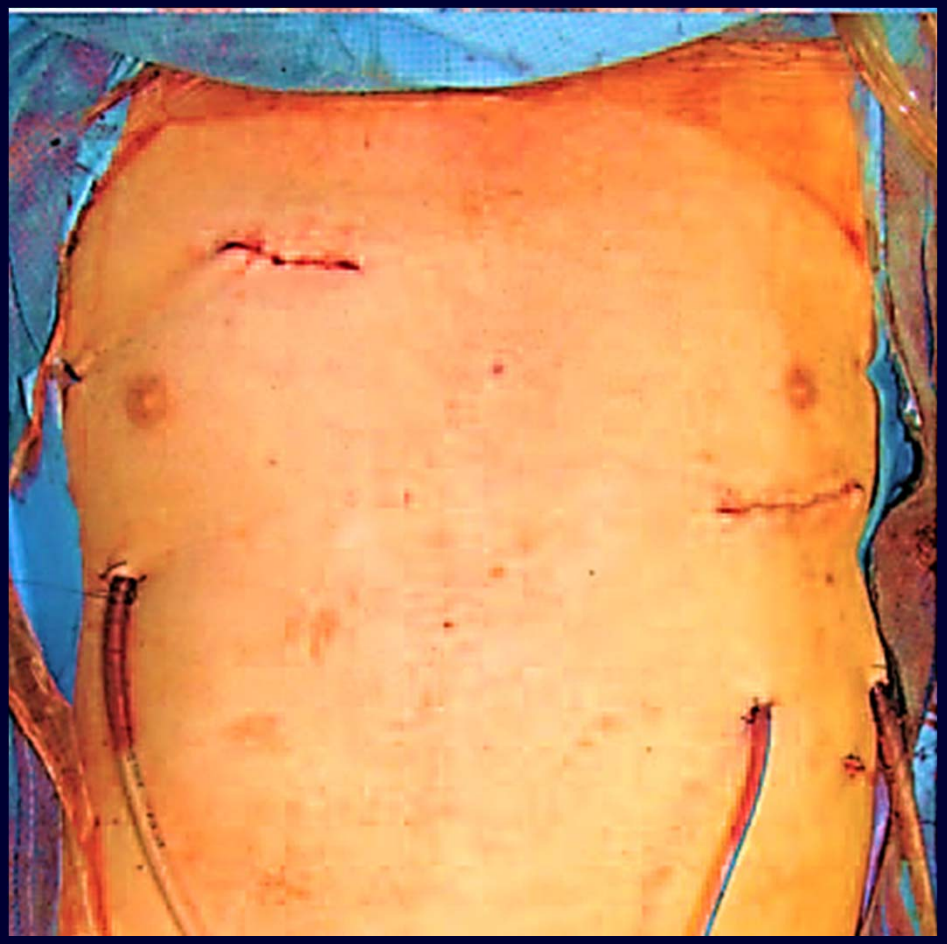
For outflow

- Inverted T
- J or L
- Thoractomy
- Infra-clavicular



Bilateral Anterior Thoracotomy Incisions

- 8cm left lateral thoracotomy
- 6cm right anterior thoractomy
- Circulatory support– fem fem or ECMO



Haberl et al. Eur J CTS 2014;46:991-996
Deuse et al. ASAIO J 2014; 60:234–236

Varying Degrees Of Invasiveness

	Standard	Thoracotomy On pump	Thoracotomy Off pump			
Full sternotomy	YES	NO	NO			
Intravenous heparin	YES	YES	YES			
Arterial & Venous Cannulation	YES	YES	YES			
CPB	YES	YES	NO			

Varying Degrees Of Invasiveness

	Standard	Thoracotomy On pump	Thoracotomy Off pump	Thoracotomy Off pump No cannulatio		
Full sternotomy	YES	NO	NO	NO		
Intravenous heparin	YES	YES	YES	YES		
Arterial & Venous Cannulation	YES	YES	YES	NO		
CPB	YES	YES	NO	NO		

Varying Degrees Of Invasiveness

	Standard	Thoracotomy On pump	Thoracotomy Off pump	Thoracotomy Off pump No cannulatio		Sternotomy Off pump No heparin
Full sternotomy	YES	NO	NO	NO		YES
Intravenous heparin	YES	YES	YES	YES		NO
Arterial & Venous Cannulation	YES	YES	YES	NO		NO
CPB	YES	YES	NO	NO		NO

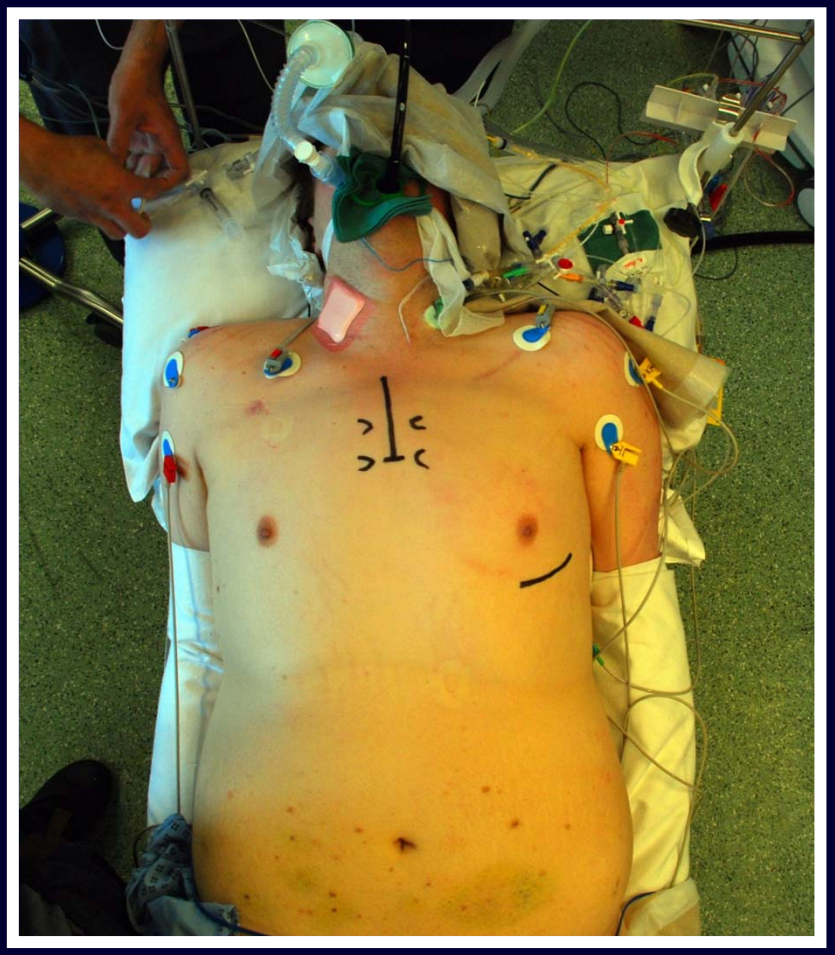
Varying Degrees Of Invasiveness

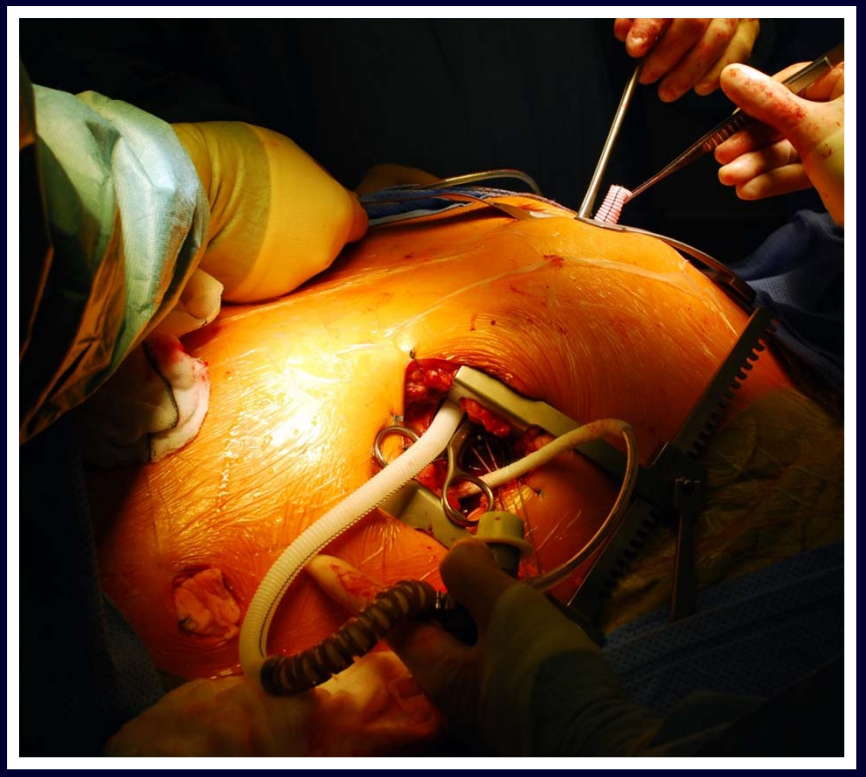
	Standard	Thoracotomy On pump	Thoracotomy Off pump	Thoracotomy Off pump No cannulatio	Thoracotomy Off pump No heparin	Sternotomy Off pump No heparin
Full sternotomy	YES	NO	NO	NO	NO	YES
Intravenous heparin	YES	YES	YES	YES	NO	NO
Arterial & Venous Cannulation	YES	YES	YES	NO	NO	NO
CPB	YES	YES	NO	NO	NO	NO

Anaesthetic Considerations

- Pre-op optimisation
- IABP
- Single lumen endotracheal tube
- Trans-oesohageal echocardiography
- **If off-pump:**
  - External defibrillation pads
  - Anti-arrhythmic e.g. amiodarone, magnesium, lidocaine
- **If no heparin:**
  - VTE prophylaxis
  - No anti-fibrinolytic
  - Belmont Rapid Infuser

J-Sternotomy & Left Anterior Thoracotomy





Contra-indications

- Concomitant cardiac surgery
  - e.g. AVR, PFO closure
- Aortic calcification
- LV thrombus
- Previous surgical ventricular restoration
- Tendency for ventricular arrhythmia

Surgical Steps

1. Left thoracotomy
2. **Inflow sewing ring**
3. Double tunnel for **driveline**
4. J-sternotomy, **Outflow graft** pull-thru' & anastomosis
5. Retrograde de-airing
6. LV **inflow** insertion

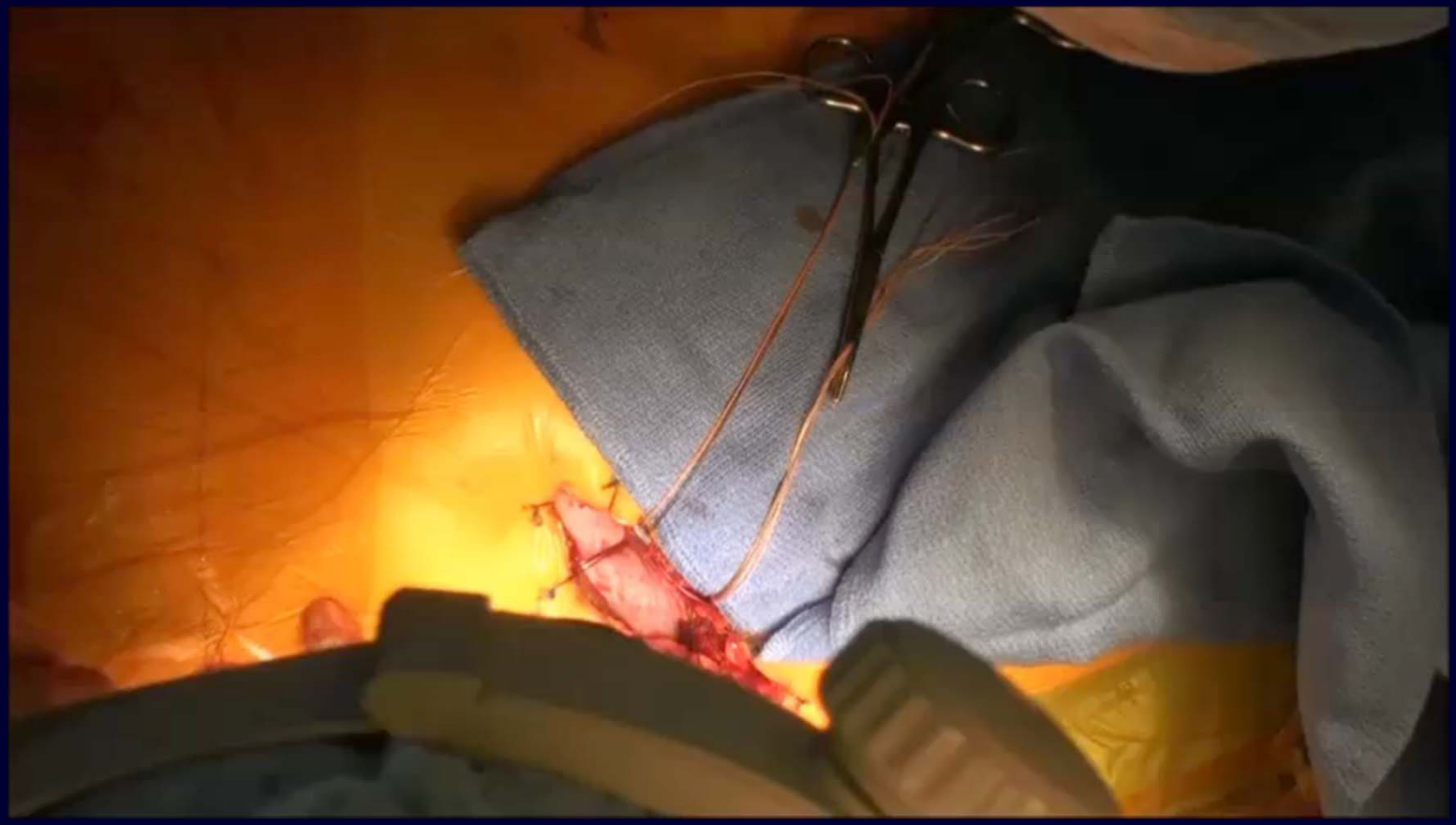
Content Warning!

The following presentation contain images that some viewers may find disturbing.

Left Thoracotomy

Inflow Sewing Ring

Double Tunnel for Driveline



J-Sternotomy & Outflow Graft

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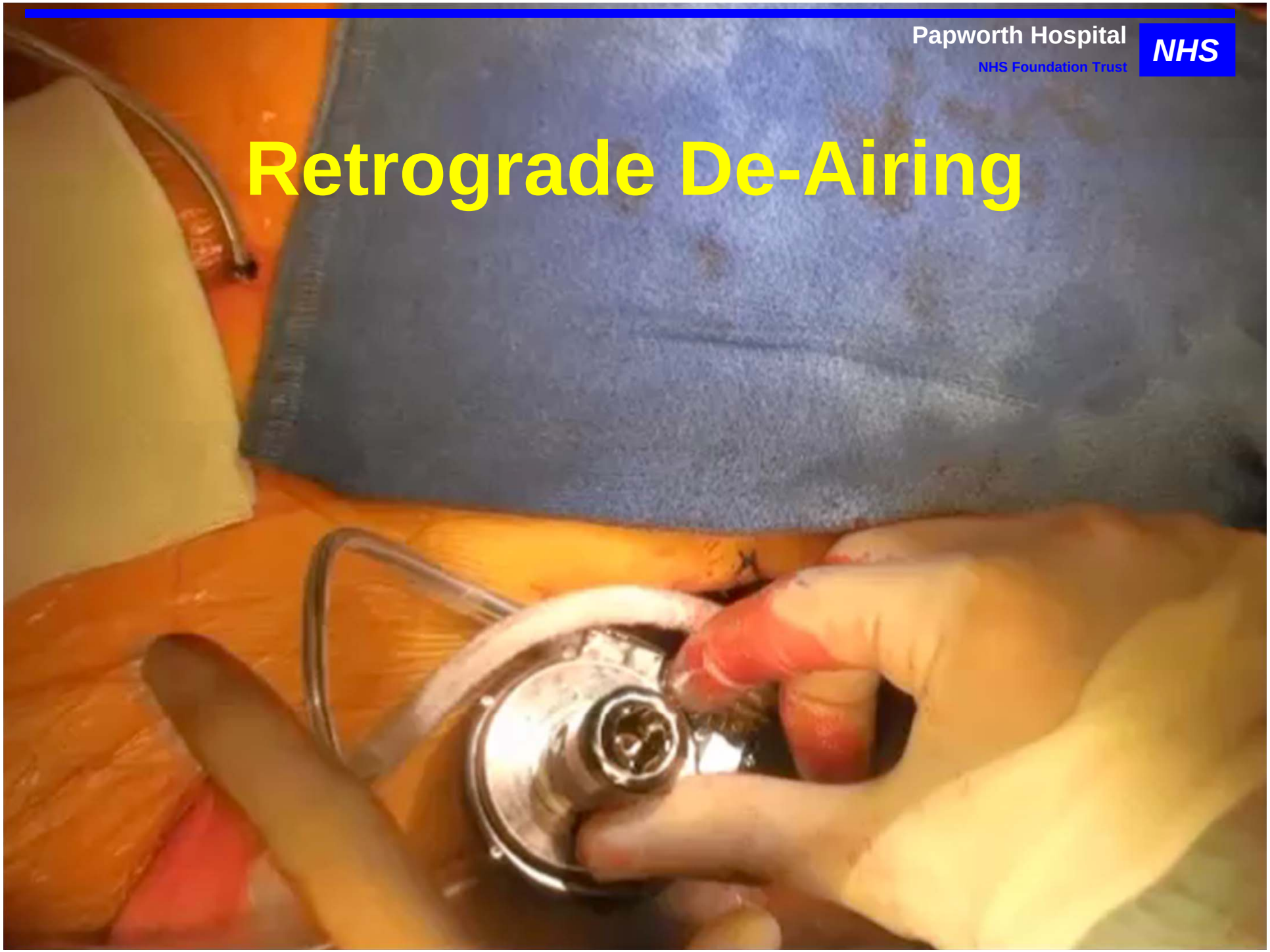
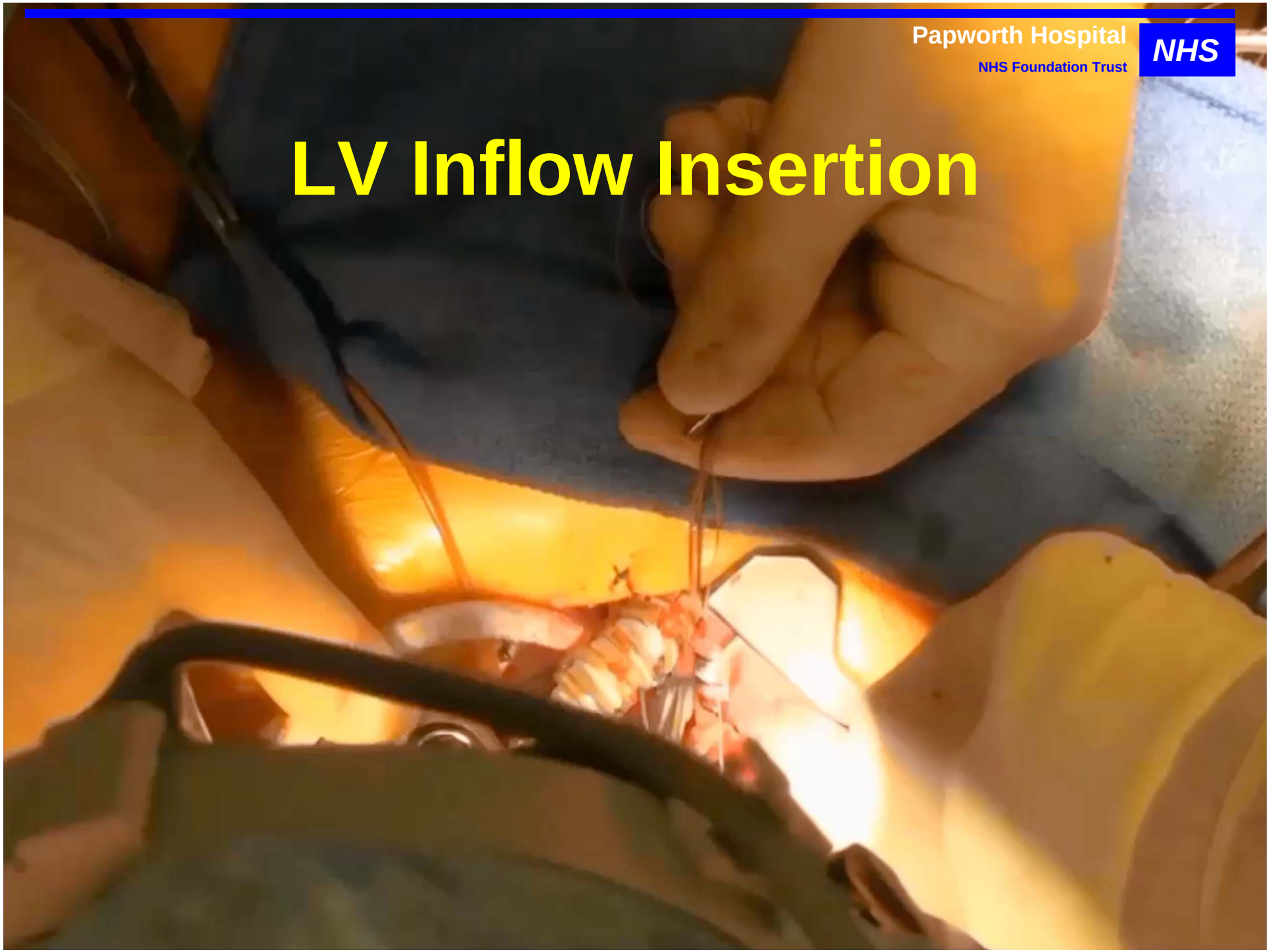
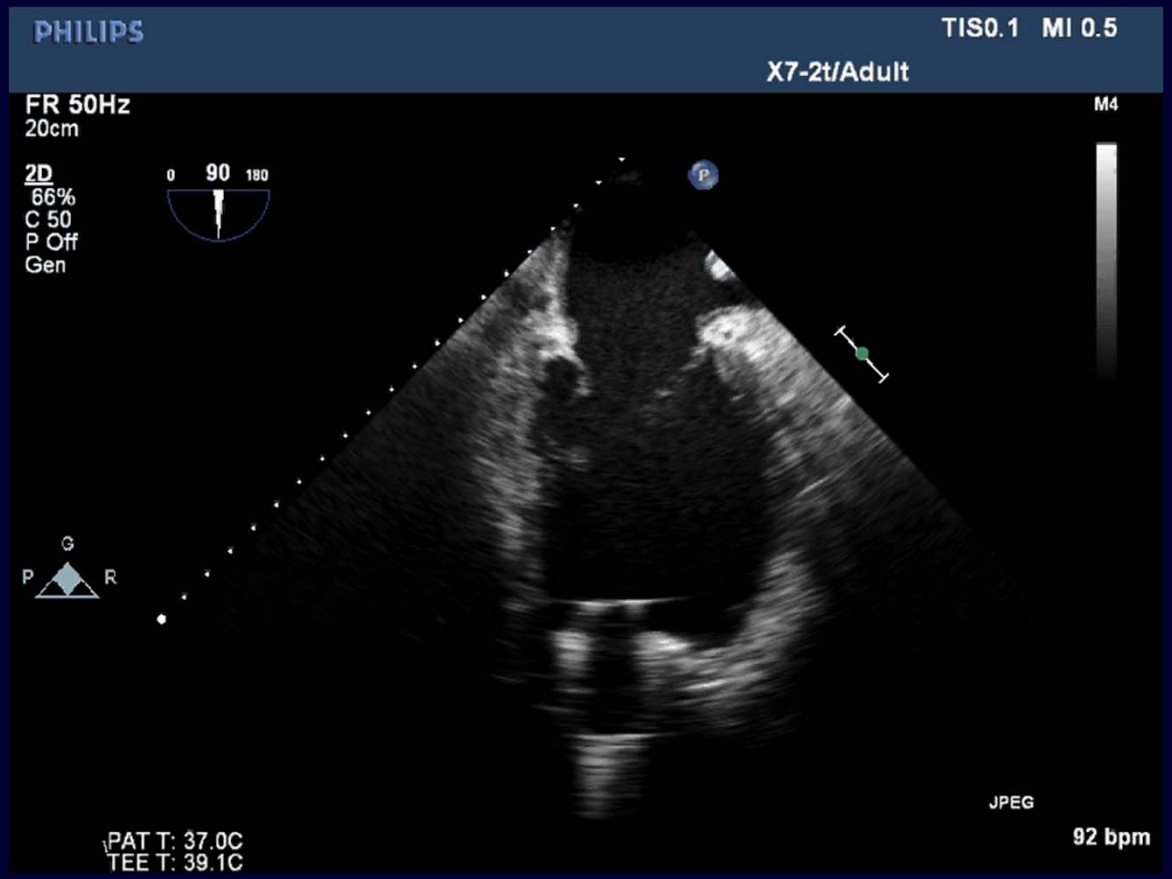
Retrograde De-Airing



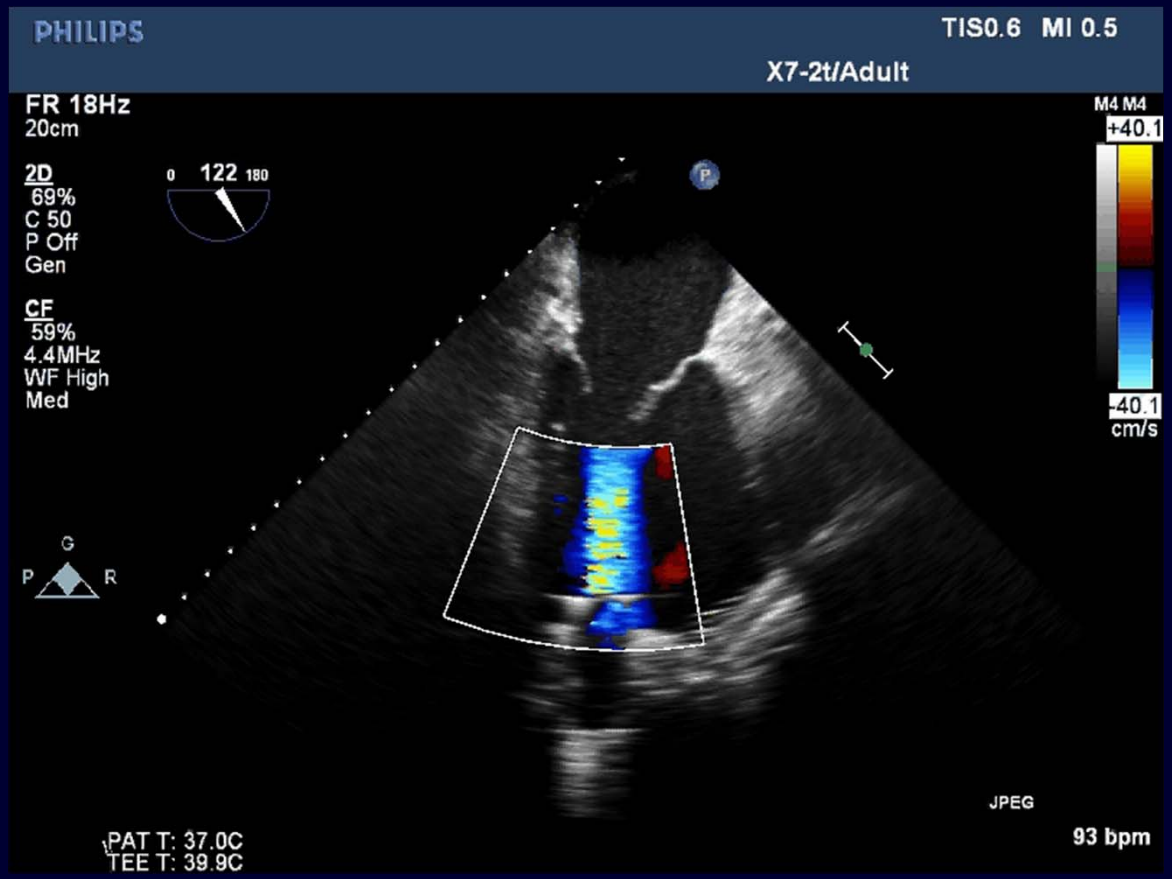
LV Inflow Insertion



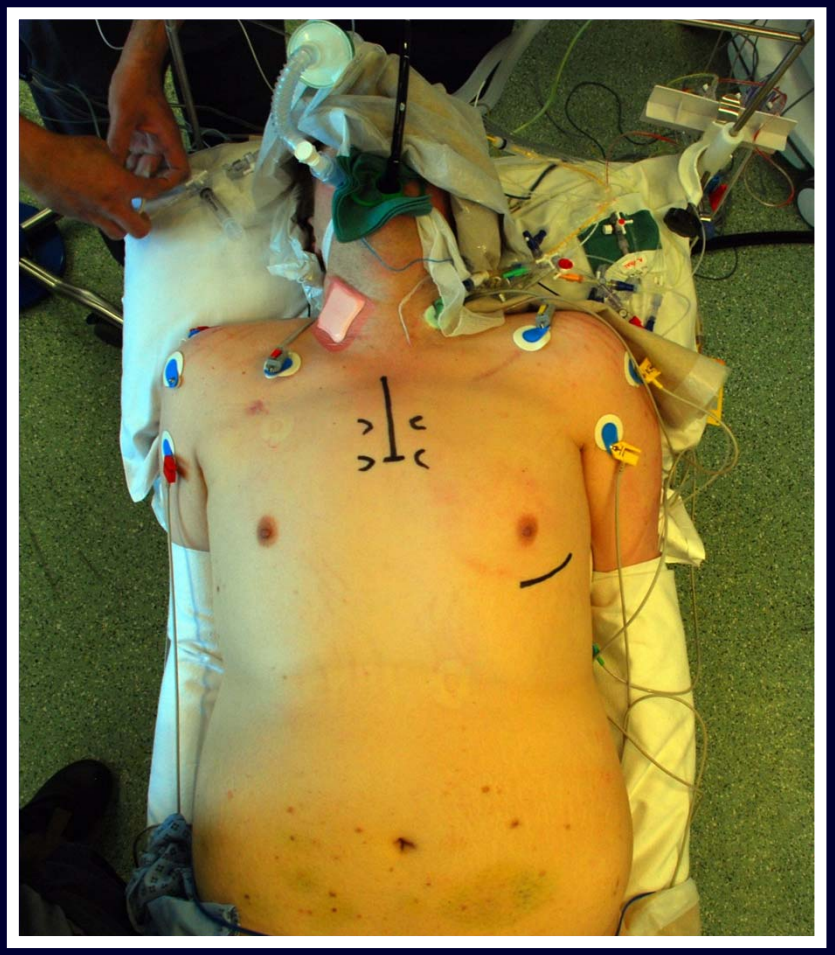
Trans-Oesophageal Echo

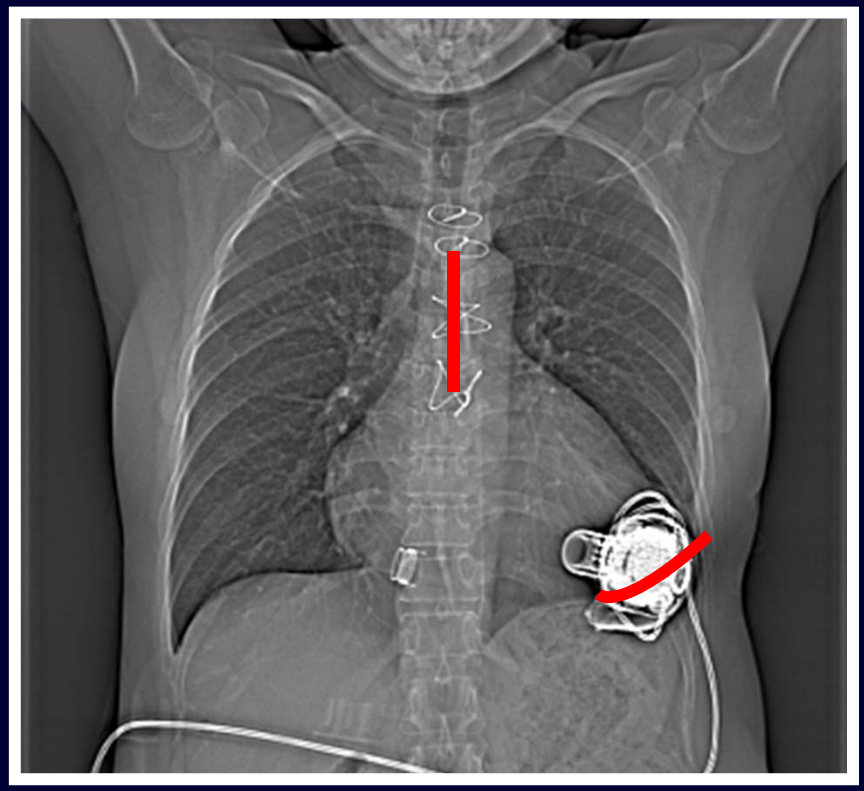


Trans-Oesophageal Echo



J-Sternotomy & Left Anterior Thoracotomy





Early Experience of Heparinless Off-Pump HVAD Implant

	Full Sternotomy		
N=	7		
Age	45.1 yo (+/-16.1)		
Gender	5M : 2F		
Conversion to CPB	0		
12-Hr Blood loss (+/- s.d.)	133 mL (+/-60)		
Re-exploration	0		
RVAD	0		

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Early Experience of Heparinless Off-Pump HVAD Implant

	Full Sternotomy	J-sternotomy + Thoracotomy	
N=	7	13	
Age	45.1 yo (+/-16.1)	50.7 yo (+/-16.0)	
Gender	5M : 2F	12M : 1F	
Conversion to CPB	0	0	
12-Hr Blood loss (+/- s.d.)	133 mL (+/-60)	240 mL (+/-120)	
Re-exploration	0	1	
RVAD	0	1	

Early Experience of Heparinless Off-Pump HVAD Implant

	Full Sternotomy	J-sternotomy + Thoracotomy	TOTAL
N=	7	13	**20**
Age	45.1 yo (+/-16.1)	50.7 yo (+/-16.0)	**48.6 yo** (+/- 15.8)
Gender	5M : 2F	12M : 1F	**17M : 3F**
Conversion to CPB	0	0	**0**
12-Hr Blood loss (+/- s.d.)	133 mL (+/-60)	240 mL (+/-120)	**201 mL** (+/- 160)
Re-exploration	0	1	**1** (5%)
RVAD	0	1	**1** (5%)

Early Experience of Heparinless Off-Pump HVAD Implant

	Full Sternotomy	J-sternotomy + Thoracotomy	TOTAL
Blood product requirements:			
RBC	1.4 +/- 2.4	2.0 +/- 2.9	**1.8 +/-2.7**
Platelets	-	-	**-**
FFP	-	-	**-**
No blood product used	4/7	5/13	**9/20** (45%)
In-hospital mortality	0/7	1/13	**1/20** (5%)

Placement of Long-term Implantable Ventricular Assist Devices Without the Use of Cardiopulmonary Bypass

Benjamin C. Sun, MD, Michael S. Firstenberg, MD, Louis B. Louis, MD, Antonio Panza, MD, Juan A. Crestanello, MD, John Sirak, MD, and Chittoor B. Sai-Sudhakar, MBBS

- Ohio State University, Columbus, Ohio
- N=25
- Full sternotomy
- Heparin maintaining ACT >300 sec.
- Ascending aortic cannulation
- Primed CPB standby

Sun et al. J HLT 2008;27:718-21

Placement of Long-term Implantable Ventricular Assist Devices Without the Use of Cardiopulmonary Bypass

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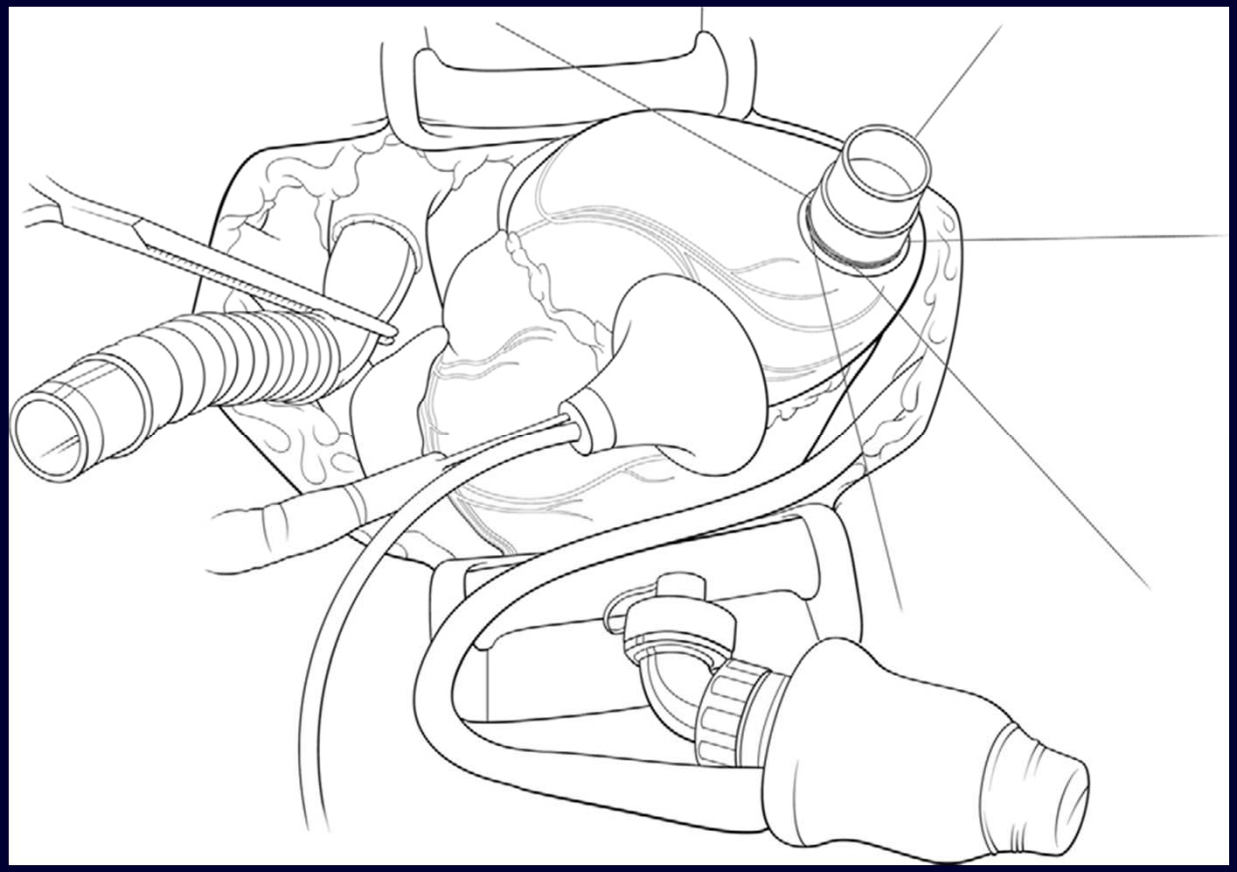

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Devices implanted	25
Thoratec HeartMate XVE	9
Thoratec HeartMate II	13
Micromed DeBakey	1
Thoratec IVAD (biVAD)	2
Destination therapy	18
Bridge to transplant	7
Intra-operative transfusions	
Packed red blood cells (units)	1.2 ± 2.5 (0–8)
Fresh frozen plasma (units)	0.6 ± 0 (0–8)
Platelets (number of 5 packs/units)	0.2 ± 0 (0–2)
Transfusions (first 24 hours)	
Packed red blood cells (units)	4.2 ± 2 (0–20)
Fresh frozen plasma (units)	3.7 ± 2 (0–20)
Platelets (number of 5 packs/units)	1.9 ± 2 (0–8)

Sun et al. J HLT 2008;27:718-21

European Journal of Cardio-Thoracic Surgery 46 (2014) 991–996
doi:10.1093/ejcts/ezu051 Advance Access publication 12 March 2014

ORIGINAL ARTICLE

Viennese approach to minimize the invasiveness of ventricular assist device implantation†

Thomas Haberl[a], Julia Riebandt[a], Stephane Mahr[a], Guenther Laufer[a], Angela Rajek[b], Heinrich Schima[c,d] and Daniel Zimpfer[a,d,*]

[a] Department of Cardiac Surgery, Medical University of Vienna, Vienna, Austria
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[c] Center of Medical Physics and Biomedical Engineering, Medical University of Vienna, Vienna, Austria
[d] Ludwig Boltzmann Cluster for Cardiovascular Research, Vienna, Austria

- Total N=27
  - Thoratec HMII N= 7
  - HeartWare HVAD N=20
- Outflow graft incision
  - Right anterior thoracotomy N=22
  - Upper sternotomy N= 3
  - Right subclavian artery N= 2
- Concomitant
  - AVR N= 1
  - TV repair N= 2

Haberl et al. Eur J CTS 2014;46:991-996

LVAD Outflow to Subclavian Artery

- 2nd rib partially resected
- outflow covered with ring-reinforced Gore-Tex graft
- 2mm PTFE band to distal subclavian artery

Reibandt et al. Ann Thorac Surg 2013:96:1094-6

Viennese Experience of Minimally Invasive LVAD Implantation

Circulatory support	
ECMO (*n*, %)	13 (48.1)
CPB (*n*, %)	9 (33.3)
Off-pump (*n*, %)	5 (18.5)
Operation time (mean, 95% CI, min)	299.3 (257.8–340.8)
Extracorporeal circulation time (mean, 95% CI, min)	89.0 (73.5–104.4)
Red blood cells (mean, 95% CI, units)	5.7 (3.5–7.8)
Fresh frozen plasma (mean, 95% CI, units)	4.0 (2.0–5.9)
Platelets (mean, 95% CI, units)	1.48 (0.9–2.0)
Ventilation time (mean, 95% CI, days)	4.1 (2.3–5.1)
ICU stay (mean, 95% CI, days)	15.9 (10.5–21.3)
In-hospital stay (mean, 95% CI, days)	42.5 (32.7–52.3)
Bleeding requiring surgical revision (*n*, %)	3 (11.1)
Ischaemic stroke (*n*, %)	2 (7.0)
Haemorrhagic stroke (*n*, %)	0 (0)

Haberl et al. Eur J CTS 2014;46:991-996

A minimally invasive off-pump implantation technique for continuous-flow left ventricular assist devices: Early experience

Martin Strueber, MD,[a] Anna L. Meyer, MD,[a] Markus Feussner, MD,[b] Joerg Ender, MD,[b] Joao-Carlos Correia, MD,[a] and Friedrich-Wilhelm Mohr, MD[a]

From the [a]Clinic for Heart Surgery; and the [b]Department of Anesthesiology, Heart Center Leipzig University, Leipzig, Germany.

- N=26
- HeartWare HVAD
- Left thoracotomy + J-sternotomy
- Heparin ACT 200-250

Strueber et al. JHLT 2014; 2014;33:851-856

Leipzig Minimally Invasive Off-Pump LVAD Implantation

Table 2 Operative Characteristics

Variable	Mean (range) ($N = 26$)
Total time in OR, min	132 (102–171)
PRBCs transfusion, units	1.2 (0–3)
Total ICU stay, days	1.5 (1–4)

Strueber et al. JHLT 2014; 2014;33:851-856

Leipzig Minimally Invasive Off-Pump LVAD Implantation

Outcome	Patients ($N = 26$) No. (%)
Peri-operative death	0 (0)
Conversion to on-pump procedure	1 (4)
Right heart failure	0 (0)
Reoperation for VAD realignment	1 (4)
Cerebrovascular accident	1 (4)
Pump thrombus requiring exchange	1 (4)

Strueber et al. JHLT 2014; 2014;33:851-856

Comparing On-pump, Off-pump & Less Invasive LVAD Implant

	N=25 OHIO (sternotomy heparin off-pump)	N=27 VIENNA (mini thoracotomies on/off pump)	N=25 LEIPZIG (Heparin Off-pump)	N=20 PAPWORTH (Heparinless off-pump)

Comparing On-pump, Off-pump & Less Invasive LVAD Implant

	N=25 OHIO (sternotomy heparin off-pump)	N=27 VIENNA (mini thoracotomies on/off pump)	N=25 LEIPZIG (Heparin Off-pump)	N=20 PAPWORTH (Heparinless off-pump)
Red blood cells	4.2 (+/-2.0)	5.7 (+/- 2.1)	1.2 (+/- 1.5)	1.8 (+/- 2.7)
Fresh Frozen Plasma	3.7 (+/-2.0)	4.0 (+/- 2.0)	?	0
Platelets	1.9 (+/-2.0)	1.5 (+/- 0.5)	?	0
Re-explore	4%	11.1%	4%	5%

Comparing On-pump, Off-pump & Less Invasive LVAD Implant

	N=25 OHIO (sternotomy heparin off-pump)	N=27 VIENNA (mini thoracotomies on/off pump)	N=25 LEIPZIG (Heparin Off-pump)	N=20 PAPWORTH (Heparinless off-pump)
Red blood cells	4.2 (+/-2.0)	5.7 (+/- 2.1)	1.2 (+/- 1.5)	1.8 (+/- 2.7)
Fresh Frozen Plasma	3.7 (+/-2.0)	4.0 (+/- 2.0)	?	0
Platelets	1.9 (+/-2.0)	1.5 (+/- 0.5)	?	0
Re-explore	4%	11.1%	4%	5%
RV Failure (RVAD/ECMO)	0%	18.5%	4% (late)	5%
ICU Stay	?	15.9 (+/- 4.4)	1.5 (1-4)	9.8 (+/- 5.2)
In-hospital stay	28 (+/- 19.0)	42.5 (+/- 9.8)	?	24.3 (+/-11.8)
In-hospital mortality	12.0%	14.8%	4%	5%

What Is Minimally Invasive?

Minimal Access $\neq$ **Minimally Invasive**

What Is Minimally Invasive?

STS Definition of minimally invasive:

Cardiac surgical procedures performed:

- **WITHOUT** full sternotomy

&

- **WITHOUT** cardiopulmonary bypass

STS Database. Spring 2007 Executive Summary. Durham, NC: Duke Clinical Research Institute, 2007.

Minimally Invasive VAD Implantation

- Lower blood loss
- Minimise blood product use
- Fewer surgical complications?
- Shorter hospital stay?
- Reduce cost?

Trade-off of Less Invasive LVAD Implant

- Minimal Access
  - Limit exposure
  - Inflow mal-alignment
  - Outflow graft problem e.g. twist, kink, etc.

Trade-off of Less Invasive LVAD Implant

- Minimal Access
  - Limit exposure
  - Inflow mal-alignment
  - Outflow graft problem e.g. twist, kink, etc.

BUT

- Off-pump should NOT mean no safety net
- Learning curve MUST be made as safe as conventional technique

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Stepwise Adoption

	Standard	Thoracotomy On pump	Thoracotomy Off pump	Thoracotomy Off pump No cannulatio	Thoracotomy Off pump No heparin	Sternotomy Off pump No heparin
Full sternotomy	YES	NO	NO	NO	NO	YES
Intravenous heparin	YES	YES	YES	YES	NO	NO
Arterial & Venous Cannulation	YES	YES	YES	NO	NO	NO
CPB	YES	YES	NO	NO	NO	NO

CONCLUSIONS

- Minimally invasive LVAD implant is promising
- Potential to reduce morbidity & cost
- Technically more demanding with potential pitfalls
- No randomised trial demonstrating benefit
- Team should be experienced with standard implant technique
- Staged adoption is reasonable & safe