

**UK National Protocol for direct retrieval and perfusion (DRP) of DCD
Hearts and Lungs with or without abdominal NRP (A-NRP) to Ex-situ
Normothermic perfusion**

Version number 1.1

Date: 1 April 2021

Responsible author; Marius Berman, co-chair of the Novel Technologies Implementation Group

Diana García Sáez, Mubbasher Husain, Anand Jothidasan, Ulrich Stock, Andre R Simon, Vipin Mehta, Rajamiyer Venkateswaran, Phil Curry, Nawwar Al Attar, Majid Mukadam, Jorge Mascaro, Jerome Jungschleger, Stephen Clarke, Jen Baxter, Simon Messer, Steven Tsui, Stephen Large, Pradeep Kaul, Mohamed Osman, Antonio Rubino, Marian Ryan, Jacob Simmonds, Julie Whitney, Dale Gardiner, Chris Watson, Ian Currie, Debbie Macklam, Jeanette Foley, Pedro Catarino, Marius Berman

DGS, MH, AJ, US, ARS – Harefield Hospital

VM, RV – Wythenshawe Hospital

PC, NAA – Golden Jubilee National Hospital, Glasgow

MM, JM – Queen Elizabeth hospital, Birmingham

JJ, SC – Freeman Hospital, Newcastle

SM, ST, SRL, PC, MO, PK - Royal Papworth

AR – Regional CLOD, DCD JIF working group 3

MR – Regional manager, ODT NHSBT

JS – Great Ormond Street Hospital

JB – Novel Technology Implementation Group – OCS operator

JW – Head of Service Delivery, ODT Hub

DG – UK National Clinical Lead for Organ Donation, NHSBT

CW – Chair, abdominal NRP working group

IC – UK Lead Organ Retrieval, NHSBT

DM – Senior Commissioning Manager – ODT NHSBT

JF – Head of Clinical Governance, NHSBT

MB – Associate UK Lead Organ Retrieval, NHSBT

Preface

This protocol was produced by a combination of clinicians covering donation, organ retrieval and transplantation, NHSBT and acquired experience for the past years. It is acknowledged that some of the details might have local variation, but, this is the overall framework we recommend to adhere to.

Index:

DCD HEART DONOR SELECTION	3
DCD HEART ASSESSMENT	4
DCD HEART Withdrawal of life sustaining treatments	4
DCD HEART Functional Warm ischaemia and Stand Down Criteria	5
Surgical protocol – NO ABDOMINAL NRP	7
Surgical protocol – WITH ABDOMINAL NRP	11
SAFETY CHECKLIST FOR DIRECT RETRIEVAL OF THE HEART/ HEART AND LUNGS AND <i>IN SITU</i> NORMOTHERMIC REGIONAL PERFUSION OF THE ABDOMINAL ORGANS	18

Protocol amendments

1. Version 1.0, date 24/03/2021 Final version approved
2. Version 1.1, date 01/04/2021 Updated clarification re DCD Heart Assessment, Section 2; minor typos

1. DCD HEART DONOR SELECTION

Donor Inclusion Criteria

- Controlled DCD (Maastricht Category 3 and 4)
- Age ≤ 50 years
- Weight ≥ 50 Kg.
- Weight ≥30 kg – if suitable paediatric recipient at GOSH or Newcastle, discuss directly with Papworth on call retrieval consultant. Refer to DCD paediatric protocol. Protocol will be updated in future once perfusion technology available for < 30kg donors.
- Consent/authorisation obtained from next of kin/ organ donor register

Donor Exclusion Criteria

- Previous cardiac surgery
- Previous midline sternotomy
- Valvular heart disease
- Congenital heart disease
- Significant coronary artery disease
- Chronic atrial fibrillation
- Insulin dependent diabetes
- Virology: HIV+
- Current IV drug abuse.
- Tumour with high risk of transmission according to SABTO guidelines

NORS team Mobilisation

- Cardiac NORS team to arrive up to 2 hours before the planned withdrawal of treatment time
- Abdominal team to arrive 1 hour before withdrawal of treatment time.
- If NRP being used, both teams must arrive at the same time as the Cardiac team (2 hours before planned withdrawal time)

2. DCD HEART ASSESSMENT

- A transthoracic Echocardiogram (TTE) will be performed for all donors and be available at the time of the offer. All efforts should be made to transfer the images for review by the implanting team prior to mobilization of the NORS DCD Heart team. If that is not possible, the retrieval team will review the images (only if they are available on arrival at the donor hospital) and communicate with the implanting team prior to withdrawal of life sustaining treatment (WLST).
- If there are no images available but a full detailed TTE report is available, the retrieval should proceed if the recipient centre is happy with the findings.
- If an echocardiogram has not been performed prior to offering, there should be no more than 3h delay in performing and conveying the results.
- If no formal echo available, explore if the ICU team will be willing to perform a Focused Cardiac Ultrasound (FCU – previously known as FICE) though this is not mandatory for the ICU. This will serve as a screening step.
- Formal TTE will be performed by donor hospital, or, trained member of the retrieval team. NO TOE (transoesophageal) echocardiography will be performed at any stage!
- If no FCU or TTE is available, heart should still be offered for transplantation. It is the responsibility of the lead transplanting surgeon to discuss with the lead retrieval surgeon regarding the offer without an ECHO. The decision to accept or decline must be made within the standard offering timeframe.
- Echo main criteria: EF > 50%, no valvular pathology, PW and/ or IVS < 15mm

DCD HEART Withdrawal of life sustaining treatments

- Withdrawal of life sustaining treatments should ideally be undertaken in the anaesthetic room / theatre complex by the local hospital intensive care team.
- If it is not local practice to withdraw in the anaesthetic room / theatre complex then it may need further discussion between retrieval and donor hospital teams, aiming to withdraw support as close to theatre as possible, in order to minimize the ischaemic time during transfer to theatre. The place of withdrawal should be agreed before the NORS team is mobilised to avoid disagreement at the point of

retrieval.

- Height of donor table should be as the same as theatre table. This is done simply by marking the height of the donor bed by tape of the SNOD trousers and match this with the theatre table height.



- SNOD – If Heart is not suitable for transplantation, please explore pathway for research approved project or valves.
- **It is recommended that the donor is transfused to Hb of ≥ 100 g/L.** Timing of transfusion - once CT NORS team is mobile.
- **Heparin in the donor before circulatory arrest**
Maastricht 3 donors: No pre-mortem interventions are currently allowed in the UK
Maastricht 4 donors (donor is already certified dead by brain stem criteria): heparin can be given.
A suggested dose is 300units/kg (around 25000 units for a 80kg person) given just prior to withdrawal of treatment
- **SNOD – prepare units of packed red blood cells (cross matched to donor) :**

- **4 units – no NRP**
- **8 units - abdominal NRP**

DCD HEART Functional Warm ischaemia and Stand Down Criteria

- After withdrawal of treatment, regular contact will be maintained with the SNOD regarding blood pressure and arterial saturations on the donor.
 - When Harefield is implanting team and the ICU team in the donor hospital are agreeable; once arterial saturation is <80% an arterial blood gas should be taken to confirm donor hypoxia, according with local hospital policy.
 - Functional warm ischaemia begins when systolic blood pressure falls below 50mmHg.
 - 30 minutes from beginning of functional warm ischaemia until cold cardioplegia is delivered will be tolerated before standing down.
 - Essential for the team diagnosing death to be familiar with the Academy of Medical Royal Colleges 2008 Code of Practice for the Diagnosis and Confirmation of Death.
 - If cardiac arrest does not occur within 120 minutes from withdrawal of treatment, consider standing down DCD heart retrieval at this stage, unless death is likely to be imminent
 - We recommend having a discussion between retrieval and recipient centres after 60 min from withdrawal.

If the donor meets criteria the OCS module should be opened at that point and the priming process started

Transfer to operating theatre

- When the donor is brought into the operating room, the SNOD shows the patient name band to confirm donor identity. If withdraw adjacent to operating theatre, if SNOD and both NORS teams are in agreement, consider confirming demographics and name band prior to withdrawal.
- **ONLY IF LUNG RETRIEVAL IS TAKING PLACE AS WELL.** Once the donor is transferred to the operating table, an endotracheal tube size above 8 is inserted.

At a point no earlier than 10 minutes after the onset of mechanical asystole, the lungs are re-inflated with a single breath of oxygen-enriched air. Lung ventilation will commence once ascending aorta is clamped, as per described in the National Standards for Organ Retrieval.

- The thoracic and abdominal surgeons will prepare the skin with an alcohol-based skin preparation solution and apply 4 drapes.
- A midline sternotomy is performed with a retractor to spread the sternal tables placed upside down. The abdominal surgeon will open the abdomen simultaneously.

Composition of the DCD CT Retrieval Team

- A theatre practitioner scrubbing for organ retrieval
- Organ preservation practitioner (OPP)
- Advanced Perfusion and Organ Preservation Specialist (APOPS)
- Two surgeons, at least one has been accredited as competent DCD cardiothoracic organ retrieval
- If aNRP, it is recommended to seek additional surgeon from Harefield or Papworth

3. Surgical protocol – NO ABDOMINAL NRP

Preparation

- Prepare St Thomas cardioplegia - Add the following medication to 500ml bag of Ringers:
 - 2,500iu of Epoetin Alfa
 - 50mgs GTN
 - 3mls Sodium bicarbonate 8.4% (840mgs in 10ml amp)
 - 10mls cardioplegia concentrate
 - Add heparin 300u/kg

(Solution to be put back into the ice box but easily accessible for use when donor arrives in theatre)

- Prepare St Thomas cardioplegia for back at implant site – Add the following medication to 1L bag of Ringers:
 - 5000iu of Epoetin Alfa
 - 100mgs GTN
 - 6mls Sodium bicarbonate 8.4% (840mgs in 10ml amp)
 - 20mls cardioplegia concentrate

(Solution to be put back into the ice box for use when heart is at implant site))

- Blood collection: Minimum of 1.2-1.5L to be collected with a raised table in head down position. It is crucial to ensure that no preservation solution is given until donor blood is drained, and no vasoconstrictor bolus is given at this stage. This should take no more than 60secs.

There are several variations across units;

- Insertion of a 2-stage venous cannula connected to a blood collection bag with Heparin 25,000 IU. If this is the case, 25,000 IU of heparin are injected into the right atrium and 25,000 IU of heparin into the pulmonary trunk prior to blood drainage.
- Insertion of a drainage cannula connected to a sucking device or sterile reservoir. Blood is drained under suction and simultaneously mixed with the

OCS priming solution containing 60000 IU of heparin

- During donor blood collection the cardiothoracic surgeon will clamp the descending aorta above the diaphragm, as low as possible. The cardiothoracic surgeon will announce this clamp is in place and the time will be recorded on the National DCD Heart Passport.
- A clamp is placed across the ascending aorta and a DLP cannula inserted into the ascending aorta for cardioplegia delivery and the heart excised in the standard fashion for heart retrieval.
- If the lungs are to be retrieved, the local hospital anaesthetist or the NORS team donor care practitioner will reintubate the donor during sternotomy as per DCD Lung retrieval.
 - Care must be taken to leave the posterior wall of PA carina when removing the heart. As soon as the heart is removed, ante-grade pneumo-plegia is delivered through these cannulae followed by retrograde pneumo-plegia via the pulmonary veins. Fibre optic bronchoscopy is performed and lungs are retrieved in standard fashion for DCD lung retrieval.

Preparation of the DRP-DCD heart prior to Ex-Situ perfusion

- The heart is immediately placed into a basin of ice cold sterile saline solution.
- Dissection made to free the aorta from the pulmonary artery placing and securing the appropriately sized perfusion connector for the Organ Care System (OCS) with the supplied cable tie. Teflon pledgeted aortic stitches are used to further secure the aorta to the OCS so reducing the risk of disconnection during travel to the recipient hospital.
- The heart is placed and de-aired onto the primed OCS.
- Insert and secure LV vent through the left atrium into organ chamber.

Place ventricular pacing wires in case pacing is required at a later stage.

PA cannula (Protocol difference)

Harefield implanting or retrieval – PA cannula secured and connected. (SVC and IVC - sutured) and connect blue flow probe – follow Transmedics protocol.

Manchester/Papworth retrieval – PA cannula NOT connected, allowing free drainage.

Three teams agreed cross over protocol at JiF DCD meeting on 28/1/2020

OCS perfusion parameters during transport:

Commence OCS perfusion of donor heart aiming for:

- Mean AOP 55-70 mmHg
- Aortic flow of 900-1100 mL/min-
- Coronary flow 650-750 ml/min
- Heart rate 70-90 BPM with V-pacing
- Once heart rhythm and perfusion are stable consider to synchronise perfusion depending on discussion with implanting team.

Acquire simultaneous AV blood samples. Perfusate targets are:

- Hct >15%
- Calcium 1.0-1.3 mmol/l
- Bicarbonate 22-29 mmol/l
- Ph – 7.3-7.45

Video clip to be transferred to implanting center at 30min reperfusion on the rig

Transport

Ensure to travel with a safety ice box and roadside bag which will include;

- Ice, cardioplegia, giving set + pressure bag, 8 litres of cold saline

Roadside bag – sterile instruments, sterile gloves different size, sterile gowns, 3 packing bags for heart.

Cardioplegia at recipient site (agreed telecom 2.9.20)

Once implanting team are happy to receive the heart,

- The retrieval team have set up to administer cardioplegia.
- All 3 teams will administer St. Thomas at retrieval and implant site when retrieving for any 6/7 UK centers.
- Harefield will carry both Custadiol and St. Thomas and will have a choice of Custadiol or St. Thomas when retrieving for Harefield.

(Refer to St. Thomas preparation on page 7)

Trouble shooting;

- Check placement heart on the rig (twist, impaired drainage..)
- Syringe drives
- Flow probes and sensors
- Module position within the rig
- Redo medication preparation

4 Surgical protocol – WITH ABDOMINAL NRP

Preparation

NRP setup

The NRP setup depends on the machine used.

The heater

Maquet's Cardiohelp: The heater is separate and should be topped up with water and switched on with the temperature set at 37°C.

Organ Assist's Donor Assist: switching on the heater is part of the automated setup.

Preparation of cold perfusion fluids

Two one-litre bags of cold University of Wisconsin solution should be prepared with 300u/kg (around 25000 units for an 80kg man) of heparin added to *each*, as for a standard DCD, and run through two giving sets so they can be used immediately should NRP fail to be established or problems are encountered during perfusion and rapid conversion to a standard technique is required. The giving set may be pre-connected to the NRP circuit and once the giving sets have been primed the UW bags should be replaced in ice until needed. When cold perfusion starts it is imperative a clamp is placed proximally to prevent back flow into the pump/reservoir.

Composition of circuit priming fluid

Standard prime

- Bicarbonate 8.4%, 1ml/kg
- Hartmann's 2000 mls
- Heparin 50,000 u
- Methylprednisolone: 1 gram
- Phentolamine 5mg
- Pancuronium 12 mg – to prevent abrupt diaphragmatic contraction when phrenic nerve is divided which can cause distress to attending teams and host staff.
- Fluconazole: 400 mg
- Antibiotics:
 - 200mg teicoplanin
 - 120mg gentamycin
 - 500mg metronidazole

Do not add gelofusine to the prime solution as it will precipitate vancomycin. *Alternatively* add the vancomycin once the circuit is running. Once the circuit is connected to the patient and running there is no longer this risk.

Anaemic donor (Hb<70gm/L)

If the donor is anaemic a unit or more of packed red cells may be added to the reservoir in place of some of the Hartmann's solution

Small donor or paediatric donor

If the donor is small the dilution effect of the prime solution will be large. Therefore:

- For donors >30kg but <50kg, add 2 units of blood to the prime and only 1L of Hartmann's.
- For donors ≤30kg, use 3 units of blood in the prime with 500mls Hartmann's.

Flow rates will be proportionately slower in smaller donors

Additional fluids during retrieval

During perfusion it is usually necessary to add more volume, in which case Gelofusine or blood are appropriate. *DO NOT ADD Hartmann's* once perfusion has started as it contains lactate and makes the lactate result impossible to interpret.

Additional heparin during retrieval

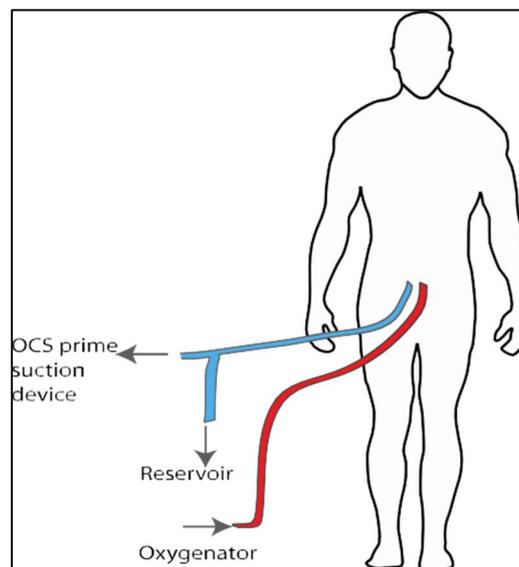
During perfusion an ACT *may* be checked or, in the absence of this, additional heparin *may* be given every 90 min at a dose of 150 u/kg.

Heparin should also be added if severe haemorrhage occurs and is replaced by a lot of bank blood, since this will dilute out any existing heparin with the risk of clotting.

Circuit

The NRP circuit needs to have a Y attachment on the venous return limb just above the reservoir, and needs to be fitted prior to arrest. This needs to be connected to the cell saver to allow for donor blood drainage needed for *ex situ* heart perfusion, but clamped initially.

-



The NRP circuit is primed with 1.5 litres of Hartmann's, to which are added 4 units of red cells.

The circuit needs to be set up before withdrawal of treatment, and warmed to 37°C by circulating through the oxygenator/heat exchanger.

A pump sucker will be connected to the reservoir for blood loss recovery. (This is the preferred standard with teams working towards this, until then existing practice will prevail). This will only be used to recover blood from the pericardium if heart retrieval only, or to recover blood from pericardium and pleural space if combined heart-lung retrieval. Blood should not be recovered from the pleural space in the presence of chest sepsis. Additional care must be taken to avoid any perfusion fluid/saline being recovered using this sucker.

THIS ADDITIONAL SUCKER WILL NOT BE USED IN CASES OF PERICARDIAL, MEDIASTINAL OR SYSTEMIC INFECTION. CAREFUL HAEMOSTASIS SHOULD BE PERFORMED IN THE CHEST EVEN IN THE EVENT OF HAVING A PUMP SUCKER AVAILABLE.

Two long DeBakey vascular clamps will be ready to use by the cardiothoracic team prior to WLST to clamp descending aorta and IVC. Two Roberts clamps will also be ready to clamp SVC and ascending aorta. It has been agreed that clamps will be provided by the abdominal team as they need to stay in place once the CTh team has left the operating theatre.

Due to the complexity of the technique all cardiothoracic organs will be perfused and retrieved only for transplantation or valve donation purposes.

Operative procedure

Following verification of death 5 minutes after circulatory arrest, the patient is transferred to the operating table.

IT IS MANDATORY TO FOLLOW THIS STEP SEQUENCE

Abdominal procedure

- 1 The circulating pump is stopped, and the sash is clamped and divided; the arterial cannula may be attached and primed at this point.
- 2 Once the donor is in theatre, the abdomen is opened through a midline incision.
- 3 The venous cannula is placed in the right common femoral vein (or iliac vein or IVC) and connected to the venous limb of the sash, with care to exclude air. Care should be taken not to insert too much length of cannula to prevent it going into the right atrium.

IF there is problem with achieving venous cannulation the thoracic team may choose to cannulate the right atrial appendage; this cannula should be removed and the appendage ligated before starting NRP or else air will be entrained in the circuit and NRP fail. For this reason atrial cannulation is a last resort.

- 4 Clamps are removed and 1.5L venous blood drained out and diverted into the collecting receptacle for the heart Organ Care System (OCS) (such as the cell saver system used by Harefield).

- 5 The Y-connector is then clamped and venous return blood now diverted to drain back into the reservoir (see figure 1). Please ensure having the correct connectors – 3/8, and ½.
- 6 The arterial cannula is placed in the right femoral artery, common iliac artery or aorta while the venous drainage occurs.
- 7 Once the cardiac team have clamped the descending thoracic aorta and stated that clearly for both teams to hear, and the 1.5L venous OCS prime has drained, the NRP pump is started aiming for flows over 2.5L/min. The time that the descending thoracic aorta is clamped will be recorded on the National DCD Heart Passport.

Abdominal NRP must not start until both teams have confirmed for all to hear that the descending aorta is clamped.

- 8 Once the heart is removed it is important to check the security of the supra-hepatic IVC clamp – this may need to be sutured in place to avoid inadvertent unclamping or slipping from the cut IVC. The cut ends of the pulmonary vessels and SVC may be oversewn with 3/0 Prolene at this stage also. While the cardiac surgeons should ensure haemostasis in the chest, in reality it is the abdominal surgeons who are usually free at this stage and can stop large vessel bleeding. There should be no major bleeding.

Heart Retrieval

The chest is opened in the midline and sternum split while the abdomen is being opened.
Pericardiotomy

Heart retrieval only

1. The left pleural space is opened and DESCENDING THORACIC AORTA IS CLAMPED above the diaphragm to isolate abdominal NRP. Priority will be given to ensure absence of brain reperfusion via NRP system. The act of clamping the descending aorta should be announced loud enough for all to hear and the time will be recorded on the National DCD Heart Passport
2. PLACEMENT OF DOUBLE LUMEN DLP CANNULA IN THE ASCENDING AORTA, as high as possible. Initially, used to drain the ascending aorta blood. Later in the sequence, it can be used for cardioplegia delivery.

Once the DLP cannula is in place and open to air, the cardiothoracic surgeon announces that the aortic arch is vented. The time will be recorded on the National DCD Heart Passport. If there is copious arterial bleeding from the DLP cannula, the NRP pump must stop and the clamp on the descending aorta must be re-positioned to occlude the aorta. Only then can the NRP pump re-start.



3. The SVC and azygous vein are dissected to ensure enough length.

4. The IVC is dissected around. If the tip of the cannula is inside the right atrium, the abdominal team should be asked to pull the cannula back below diaphragm to allow for IVC clamping at a later stage. Check to ensure the venous cannula does not encroach into the right atrium.

The heart is assessed for any visible anomalies, palpable coronary artery disease, left ventricular hypertrophy, trauma, congenital disease etc.

5. Once 1.3-1.5L of donor blood has been received into the receptacle / cell saver for the OCS prime, **CLAMPS ARE PLACED ACROSS THE IVC ABOVE THE DIAPHRAGM, AND THE SVC CAUDAL TO THE AZYGOS.** The SVC is transected caudal to clamp, placed below azygos vein.

6. The ascending aorta is clamped, in addition to the descending thoracic aortic clamp.

7. IVC is opened just cranial to the clamp for venting and left atrium is opened at level of pulmonary veins for pulmonary return.

8. Cardioplegia supplemented with 25000 IU heparin, EPO and 50 mg of GTN is administered via a large bore needle **PROXIMAL** to the cross clamp. The previously placed DLP cannula, distal to the cross clamp, at the level of the arch will remain in situ and open to air.

9. Once cardioplegia is finished, the large bore cannula is removed.

10. The heart is then excised leaving all previously placed clamps in situ to minimize blood loss.

11. Establish with the abdominal team and identify team member who is going to secure potential bleeding points. – stich 3/0 stump IVC (with or without the clamp), SVC, azygos and pulmonary veins.

12. The heart graft is prepared at the back table and re-perfused with ex situ normothermic perfusion technology in the usual manner.

Heart and Lung retrieval

Once the donor is transferred to the operating table, an endotracheal tube size above 8 is inserted. At a point no earlier than 10 minutes after the onset of irreversible asystole, the lungs are re-inflated with a single breath of oxygen-enriched air. Lung ventilation will commence once ascending aorta is clamped, as per described in the National Standards for Organ Retrieval. Bronchoscopy performed usually at this point if an additional surgeon is available, or later after pneumoplegia completion.

1. The left pleural space is opened and DESCENDING THORACIC AORTA IS CLAMPED. The act of clamping the descending aorta should be announced loud enough for all to hear and the time will be recorded on the National DCD Heart Passport.

2. Placement of double lumen DLP cannula in the ascending aorta, and cannula opened to air; This cannula is used initially to ensure absence of brain perfusion and later used for cardioplegia delivery.

Once the DLP cannula is in place and open to air, the cardiothoracic surgeon announces that the aortic arch is vented. The time will be recorded on the National DCD Heart Passport. If there is copious arterial bleeding from the DLP cannula, the NRP pump must stop and the clamp on the descending aorta must be re-positioned to occlude the aorta. Only then can the NRP pump restart.

3. SVC, IVC dissection and donor blood drainage, as per heart only retrieval technique, is performed.

4. Clamps are placed across the IVC above the diaphragm and the SVC caudal to the Azygos. The IVC is opened just proximal to the clamp for venting and the left atrial appendage is vented widely.

5. The ascending aorta is clamped, proximal to DLP cannula, only during cardioplegia delivery. Cardioplegia supplemented with 25000 IU heparin, EPO and 50 mg of GTN is administered via a large bore needle PROXIMAL to the cross clamp. The previously placed DLP cannula, distal to the cross clamp, at the level of the arch **will remain in situ and open to air.**

6. Once cardioplegia is finished, the large bore cannula is removed.

7. After cardiectomy, antegrade pneumoplegia is completed according to National protocol. Simultaneously, the pleurae are opened widely and lungs inspected and palpated, ensuring adequate delivery of flush and topical cooling with copious volumes of 4°C saline.

8. If significant collateral flow from pulmonary veins, consider delivering retrograde pneumoplegia into the pulmonary veins

9. After completion of antegrade pneumoplegia, wait for aNRP to reach 30 min, prior to starting dissection.

10. After 30 min, inform everyone in theatre that CT surgeons start lung dissection.

11. If the lungs are suitable and accepted for transplantation a competent lung retrieval surgeon will complete rest of dissection while abdominal NRP continues, by dividing the descending thoracic aorta and taking this along with the lung bloc. This would involve ligaclipping all the intercostal arteries (L and R) up to the arch, being careful to avoid bleeding.

The care and detail required to retrieve lungs whilst NRP is running is the same as would be required in a living patient. The abdominal organs may be lost if the lung retrieval is performed in haste. If we are to build a future with novel technologies, both teams need to support maximal organ retrieval and utilization.

Consider applying a second clamp on the descending thoracic aorta, just distal to left subclavian artery, in order to minimize bleeding. We recommend removing the lung block with the thoracic aorta, however, some might feel more comfortable dissecting in front of the aorta. Need to bear in mind the left pulmonary artery when dissecting in this plane.

12. **The azygos vein must be ligated twice and cut in between.** This can be done easily in the right pleural space.

The rest of the lung dissection can be completed with diathermy and by using surgical Liga-clips aiming to minimize blood loss.

13. The trachea is stapled and cut leaving a clamp or staple line on the top end.

14. Retrograde pulmonary venous flush of the lungs is performed on the back-table at the donor site and lungs are packed as per National protocol.

Lung retrieval only

Once the donor is transferred to the operating table, an endotracheal tube size above 8 is inserted. At a point no earlier than 10 minutes after the onset of irreversible asystole, the lungs are re-inflated with a single breath of oxygen-enriched air. Lung ventilation will commence once ascending aorta is clamped, following all steps as per the National Standards for Organ Retrieval.

Bronchoscopy performed usually at this point if an additional surgeon is available, or later after pneumoplegia completion.

1. The left pleural space is opened and DESCENDING THORACIC AORTA IS CLAMPED.
The act of clamping the descending aorta should be announced loud enough for all to hear and the time will be recorded on the National DCD Heart Passport.
2. Placement of double lumen DLP cannula in the ascending aorta to ensure absence of brain perfusion
Once the DLP cannula is in place and open to air, the cardiothoracic surgeon announces

that the aortic arch is vented. The time will be recorded on the National DCD Heart Passport. If there is copious arterial bleeding from the DLP cannula, the NRP pump must stop and the clamp on the descending aorta must be re-positioned to occlude the aorta. Only then can the NRP pump re-start.

Place pneumoplegia cannula into the PA.

Clamp proximal PA .

Cut LA appendage.

3. Antegrade pneumoplegia as per UK National guidelines is administered. Simultaneously, the pleurae are opened widely and lungs inspected and palpated, ensuring adequate delivery of flush and topical cooling with copious volumes of 4°C saline.

CT WILL WAIT after delivering antegrade pneumoplegia to complete 30min aNRP perfusion prior to carry on any further dissection. CT NORS might choose to use this time to repeat FOB or assess in more detail the lungs.

THIS WILL ALLOW ESTABLISH OF aNRP flows for at least 30min, period crucial to liver recovery. Risk of bleeding is minimal at this stage.

4. Ascending aorta is clamped proximal to DLP cannula, and cannula should be open to air to ensure absence of brain perfusion.
5. SVC, IVC dissection is performed. Clamps are placed across the IVC above the diaphragm and the SVC caudal to the Azygos. The IVC is opened just proximal to the clamp for venting and the left atrial appendage is vented widely.
6. Heart -lung retrieval will be carried en-bloc. This is to minimize potential catastrophic blood loss.
7. Cardiectomy performed leaving a **long IVC cuff above previously placed IVC clamp**. Ascending aorta and SVC are both cut caudal to clamps, which stay in place to avoid bleeding.
8. If the lungs are suitable and accepted for transplantation the rest of dissection will be completed while abdominal NRP continues, being careful to avoid bleeding.

The care and detail required to retrieve lungs whilst NRP is running is the same as would be required in a living patient. The abdominal organs may be lost if the lung

retrieval is performed in haste. If we are to build a future with novel technologies, both teams need to support maximal organ retrieval and utilization.

9. **The azygos vein must be ligated twice and cut in between.** This can be done easily in the right pleural space.
10. The rest of the heart-lung bloc dissection can be completed with diathermy and by using surgical Liga-clips aiming to minimize blood loss.
11. The trachea is stapled and cut leaving a clamp or staple line on the top end
12. Secure major remaining stumps – IVC, SVC, arch vessels and any other source of bleeding.
13. Retrograde pulmonary venous flush of the lungs is performed on the back-table at the donor site and Lungs are packed as per National protocol.
14. **Heart to be returned into the chest and document this action.**

The cardio-thoracic surgeon should ensure haemostasis in the chest during and at the end of retrieval, before leaving the donor hospital. Excess bleeding may result in an unusable liver, pancreas and kidneys.

Requirements to undertake DRP and NRP

The following are required for the successful removal of the heart during NRP

From the cardiac team

- Senior surgeon who is experienced in DRP retrieval
- The *ex situ* normothermic heart perfusion machine. Technician to operate the *ex situ* perfusion machine and the cell saver
- The necessary sterile tubing and adapters to connect to the NRP circuit (3/8 and ½ inch tubing). An appropriately staffed and equipped lung retrieval team if the lungs are also being retrieved

From the abdominal team

- Senior surgeon who is experienced in NRP
- The NRP disposable circuit
- NRP heater/cooler and pump (e.g. Cardiohelp)
- Experienced NRP perfusion practitioner
- 2 x long vascular clamps for descending aorta and IVC clamping

From the SNOD

8 units of bank blood, 4 to be added to prime

OCS perfusion parameters during transport:

In general, it is recommended to maintain the OCS in manual rather than automatic mode.

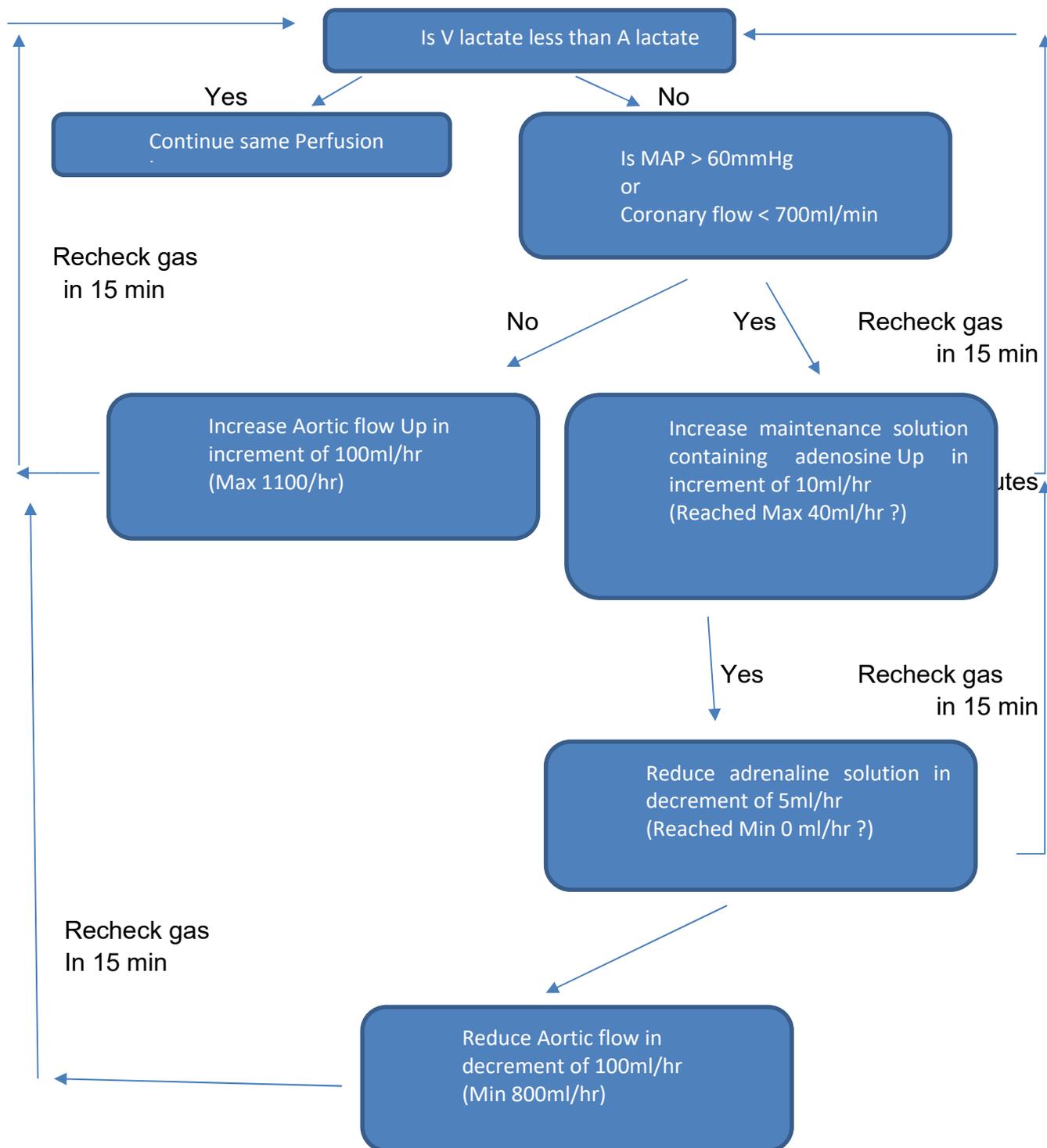
Mechanical manipulations, such as flow and pacing, have a faster effect than infusions adjustments.

Commence OCS perfusion of donor heart aiming for:

- Mean AOP 55-70 mmHg
- Aortic flow of 800-1100 mL/min-
- Heart rate 70-90 BPM with V-pacing
- Aim CF 650-750 ml/min
- Once heart rhythm and perfusion are stable consider to synchronise perfusion depending on discussion with implanting team.

Acquire simultaneous AV blood samples. Perfusate targets are:

- Hct >15%
- Calcium 1.0-1.3 mmol/l
- Bicarbonate 22-29 mmol/l
- Ph – 7.3-7.45



SAFETY CHECKLIST FOR DIRECT RETRIEVAL OF THE HEART/ HEART AND LUNGS AND *IN SITU* NORMOTHERMIC REGIONAL PERFUSION OF THE ABDOMINAL ORGANS

TO BE COMPLETED AT HANDOVER

CTH SURGEON

ABDO SURGEON

1 Protocol reviewed prior to WLST

2 Debrief completed prior to WLST

3 CTh team equipment ready

(Cell saver, Clamps, OCS, Fluids for perfusion)

4 Abdominal team equipment ready

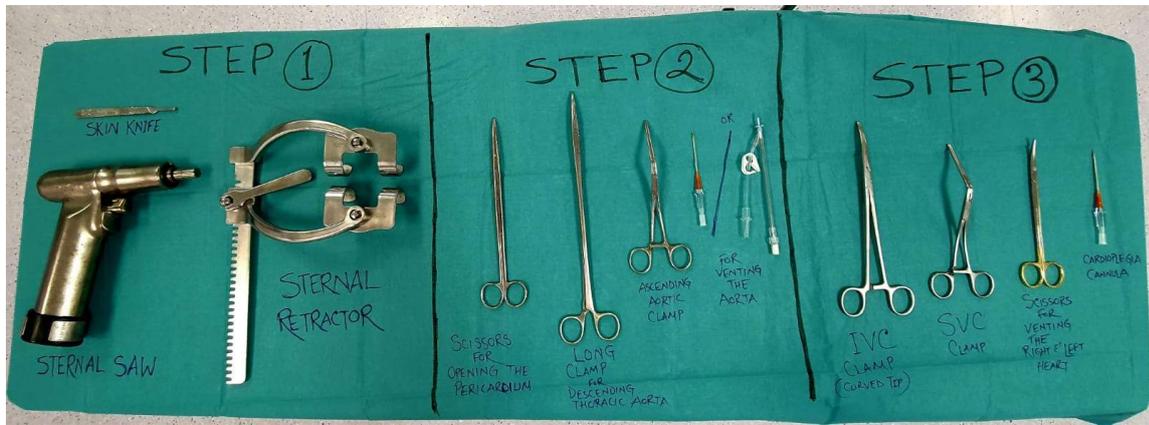
Leading surgeon; Full name and signature

TO BE COMPLETED PRIOR TO START ABDOMINAL NRP

(Time to be noted and signed by Abdominal team Perfusionist)

1 Descending Aorta x clamp time

Scrub trolley discipline:



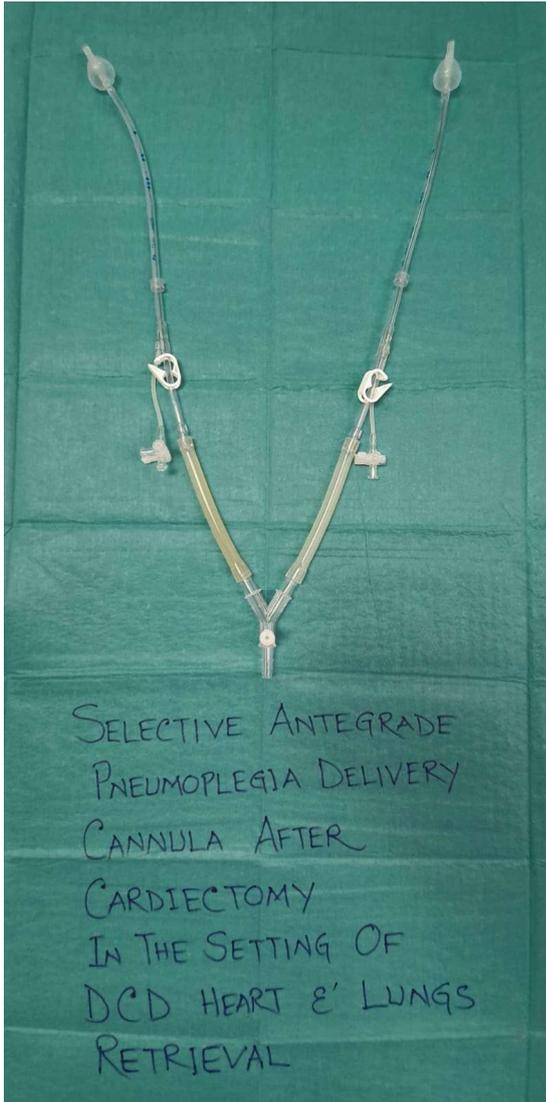
The above figure demonstrates the scrub trolley discipline, which correlates with the surgical steps, and this can be very helpful in the DCD with A-NRP retrieval specially at the very beginning of the process till the start of the antegrade cardio and pneumoplegia. This is not only helpful but also comfortable for the surgeons and the scrub to work in harmony and to prevent unwanted events as well as to maintain sterility in a hasty procedure.

Some teams would prefer a second trolley is prepared for the assistant and will be on the left of the donor

The trolley contains: SEE PHOTO

- Two suckers (Cell saver and wall sucker (Cell saver marked by a black tie to distinguish from wall sucker and not be used once cardioplegia started)
- Clamp for the SVC
- Two Dunhill clips.
- One Abdo pack
- Heparin syringe
- Two forceps
- Chest retractor
- Cardioplegia and pneumoplegia lines.





In the setting of DCD heart and lungs retrieval cardioplegia delivery finishes before pneumoplegia. But, if one has to wait for the pneumoplegia to finish before starting procurement of the heart, several precious minutes will be lost. To avoid that as soon as cardioplegia delivery finishes, antegrade pneumoplegia delivery can be paused for procurement of the heart. After that through the cut end of main pulmonary artery the selective antegrade pneumoplegia delivery cannula (shown in the figure) can be used to complete the rest of the pneumoplegia.

Cardiothoracic Synchrony between the Surgeons

<u>SURGEON 1</u>	<u>SURGEON 2</u>
<ul style="list-style-type: none"> • Skin Incision • Sternotomy 	Handle the suckers and the plegia lines
	<ul style="list-style-type: none"> • Placing the Sternal retractor (Not fully opened in order not to stretch the pericardium
<ul style="list-style-type: none"> • Opening of the pericardium • Opening of the Left pleura • Retracting the Left lung to expose the descending thoracic aorta 	
<ul style="list-style-type: none"> • Inject heparin in right atrium 	Inject heparin in PA
	<ul style="list-style-type: none"> • Clamping the Descending Thoracic Aorta with a long clamp
<ul style="list-style-type: none"> • Incising right atrial appendage and collection blood for OCS 	
<ul style="list-style-type: none"> • Ascending Aortic clamp • Insertion of venting needle distal to the clamp 	
	<ul style="list-style-type: none"> • Securing the venting needle/cannula
<ul style="list-style-type: none"> • Rule out CAD 	
<ul style="list-style-type: none"> • Venting the Right (Clamping the IVC in the pericardium and Flush cutting) and Left Heart (through LAA or LSPV) • Inserting with wide bore cannula (medicut) and holding it in place proximal to the ascending aortic clamp to deliver antegrade cardioplegia 	<ul style="list-style-type: none"> • SVC clamp caudal to Azygos away from SA node
	<ul style="list-style-type: none"> • Connecting the cardioplegia line to the cannula • Surface cooling with cold saline

<ul style="list-style-type: none"> • At the completion of the cardioplegia, careful procurement of the heart (after securing the Azygos and ensuring adequate SVC length) 	<ul style="list-style-type: none"> • Helping the Surgeon 1
<ul style="list-style-type: none"> • Heart out and preparing it for OCS in the back table 	
	<ul style="list-style-type: none"> • Securing bleeding points and ensuring haemostasis for a smooth A-NRP run