MIXED-VENOUS SO₂ IN ECC: A RELEVANT PARAMETER FOR PERFUSION EVALUATION? REGIONAL SHUNTING OF BLOOD FLOW DURING HYPO- AND NORMOTHERMIA

Background: Mixed-venous SO₂ is a generally accepted parameter of perfusion evaluation. Lowering the patient’s body temperature to reduce metabolic activity and oxygen consumption especially for complex surgical procedures is state of the art in perfusion. Aim of our study was to determine in hypothermia and during controlled rewarming to normothermia the relationship between mixed and regional venous SO₂ of SVC and IVC, as well as the influence of temperature on regional distribution of ECC-pump flow.

Method: The prospective controlled study encompasses 30 patients who underwent a Ross-operation from May 2001 to May 2003. In the standard Regensburg-ECC-system only the venous line was modified to allow separate blood gas and flow measurements (Transonic Flowmeter® T110) of SVC, IVC and combined venous line. ECC management included pump flow constant at 2,6 l/min/m², moderate hypothermia (28°C) and β-stat blood gas management. Nine measurement points were defined, three pre- and post-ECC and six during ECC exclusively during aortic cross clamp time (148 ± 32 mins). Water temperature of ECC was kept at 25°C for 30 minutes and then gradually increased every 20 minutes up to 38°C. Art. and ven. blood gases and mixed venous saturation were measured online (CDI 500). Cerebral saturation (rSO₂) was measured continuously by infrared spectroscopy (INVOS). Furthermore, temperature progression at different sites was monitored: art. and ven. blood, tympanic, bladder, rectal, pulmonary artery, and skin.

Results: SO₂ of IVC was significantly lower than SO₂ of SVC and mixed-venous SO₂ at all measurement points and decreased above 32°C more pronounced down to values below 60% in normothermia. There was a positive statistically significant correlation between SO₂ of IVC and mixed-venous SO₂ and also temperature. No correlation, however, between SO₂ of SVC and mixed-venous SO₂. ECC pump flow drained over SVC and IVC in an approx. ratio of 2:3, IVC 57% to max. 65% of total pump flow. The correlation of SVC drainage with temperature, i.e., less in hypothermia and increasing with temperature was significant. There was no correlation between perfusion pressure and drainage of SVC. rSO₂ correlated with drainage of SVC and temperature but not with mixed-venous SO₂ or perfusion pressure.

Conclusion: Mixed-venous SO₂ correlates strongly with SO₂ of IVC yet has only limited predictive value concerning regional O₂-supply as marked regional hypoxia can occur despite normal mixed-venous SO₂ during rewarming. Cerebral blood flow autoregulation during moderate hypothermia (~ 28°C) and β-stat blood gas management is maintained. An increase in ECC pump flow should therefore benefit the IVC compartment.

We report on a 3.69 kg male neonate with transposition of the great arteries that underwent arterial switch operation with cardiopulmonary bypass (CPB) without transfusion of blood components during the bypass period. Extended and complex CPB was performed without excessive hemodilution. Hemoglobin concentration (Hb) was maintained in a safe range during the entire 2 hours 47 minutes of extracorporeal circulation.

Our minimized circuit had a priming volume of approximately 180 ml and consisted of a balanced electrolyte solution and heparin only. A special designated neonatal CPB console (Mastpump, Stoeckert, Munich, Germany) was brought into close proximity to the operation table. Tubing length was shortened by positioning the arterial roller pump close to the oxygenator (Safe Micro, Polystan, Vaelrose, Denmark) and the cardiotomy roller pumps close to the cardiotomy reservoir. All tubing diameters were downsized to 3/16”; only the roller pump segments consisted of ¼” tubing. An arterial line filter (Newborn, Dideco, Mirandola, Italy) was also integrated.

After the start of CPB, moderate hypothermia (28°C) was induced. With a hypothermic arterial bypass flow of 550 ml/min venous return was achieved by gravity venous drainage. With the onset of rewarming venous drainage was augmented by vacuum-assist to achieve a maximum bypass flow of 4 l/min/m². No hemofiltration was performed during CPB; the hemofilter was left unprimed. Hb before CPB was 14.5 g/dl and the highest Hb during CPB was 9.5 g/dl. The lowest Hb of 7.8 g/dl was measured after infusion of the cardioplegic solution. After termination of CPB Hb was 8.2g/dl. Subsequently, the blood volume of the venous line was used to prime the hemofilter system (DHF-02 Dideco), and modified ultrafiltration was performed. Donor blood components were transfused after termination of CPB to achieve the desired target Hb of 12 g/dl and to support coagulation. The patient was weaned from the ventilator after 3 days.

CPB without blood priming and avoidance of arterial transfusion of packed red cells eliminates a potential source of arterial emboli consisting of microaggregates. Negative side effects of pharmaceutical additives and metabolites from donor blood are also avoided during CPB.

With this strategy, we have been able to safely perform neonatal CPB without arterial transfusion of blood components in selected patients. The patient described had the lowest body weight.

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MANAGEMENT OF EXTRA-CORPORAL CIRCULATION IN HEART SURGERY
THROUGH A RIGHT MINI-THORACOTOMY

Background: Minimally invasive open-heart surgery requires cardiopulmonary bypass (CPB) to be initiated via peripheral access. We report about our initial experience with a modified femoro-femoral CPB, while the superior vena cava being drained by a supplementary cannula inserted via jugular vein. However, due to smaller diameter of the cannula a slight modification of the CPB was necessary to improve the impeded venous return.

Methods: Cannulation of the superior vena cava was performed through the right jugular vein by the maintenance of anesthesia. After right mini-thoracotomy and exposure of the femoral site, CPB was initiated by cannulation of the femoral artery, and the inferior vena cava via the femoral vein using the Heartport® system. A modified open CPB system (Jostra®) was used. In order to improve the venous return, the venous reservoir was completed with a device offering undertow that was monitored by a low pressure valve in the venous and a vacuum controller in the arterial line. Myocardial protection was performed by Bretschneider’s solution. A minimal (7-9cm) right thoracotomy through the fourth intercostal space was used in all cases as the surgical approach. All procedures were performed video-assisted.

Results: During our initial experience between April–October 2002, 9 patients (pts) were operated on using this technique (7 males/2 females, age 52.6±9.5 years, body weight 78.7±19.4 kg, body surface area 1.94±0.3 m²). Seven patients were operated on for mitral valve repair/replacement and 2 pts for closure of an atrial septal defect. Cannula sizes were 18-20 Fr for the femoral artery, 25 Fr for the femoral vein, and 16 Fr for the superior vena cava. Considering the theoretical perfusion flow of 5.5 l/min, the venous flow through both cannulae was 4.27±0.5 l/min. Mean CPB and cross-clamp times were 141.7±38.6 min and 87.5±24.5 min, respectively. Minimum venous saturation was 97.4%±1.8 %. There were no cases of hospital or late postoperative mortality. No case of postoperative adverse events occurred. All pts were extubated within 8 hours postoperative and discharged from ICU by the first postoperative day.

Conclusions: Despite our limited initial experience, and considering the smaller internal diameter of percutaneous cardiopulmonary bypass cannulae compared to classic one, the modifications of the CPB system we used in this study improved the venous drainage significantly, so that minimally invasive open heart procedures could be performed under optimal CPB-conditions in our center.

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SIGNAL PROCESSING OF THE PRIMARY ELECTRICAL SIGNAL FOR THE TRIGGER CONTROLLED INFLATION PHASE USING THE INTRA-AORTIC BALLOON PUMP DATASCOPE SYSTEM 98 XT AS EXAMPLE

Introduction: The intra-aortic balloon pump is a device for mechanical support of the heart, which increases the coronary artery perfusion during diastole and decreases the impedance of the heart (afterload) just before systole, reflected by increased cardiac output. This results in improved oxygen demand for the myocardium. To achieve a proper inflation and deflation timing of the intra-aortic balloon during the cardiac circle a safe detection of the trigger is essential.

Issue: This poster should give you a short overview of the pathway of the ECG as an example for an primarily electrical signal of the upper chest, used by the intra-aortic balloon pump Datascope 98 XT.

Solution: In order to achieve a smooth inflation period of the IABP adjusted to the cardiac cycle a safe and timely detection of the trigger is crucial. This can be done by amplifying, modulating and filtrating the incoming signal (ECG) in such a way that it is reduced to the necessary trigger (R-wave).

Discussion: Thanks to the increasing speed of data processing better algorithm can be implemented to avoid malfunction of the IABP. Due to safe detection and use of the trigger signal a correct inflation period during the cardiac cycle can be achieved, which leads to a hemodynamic stabilisation of the patient.

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MULTIFUNCTIONAL MODES OF APPLICATION FOR A MINIMISED ECC-SYSTEM

Background: The various application options of a minimized ECC-System (MECC) are presented. Safety of the extracorporeal circulation (ECC) has to have highest priority even in infrequent interventions. Derived from the routine application of the MECC-System for CABG operations usage of the system for a broad spectrum of specific ECC-applications was evaluated.

Description of the system: The completely heparin-coated system consists of centrifugal pump and membrane oxygenator. Priming volume (approx. 500 ml) and foreign surface are minimized. The closed system contains neither reservoir nor machine sucker, therefore there is no blood–air contact. Volume is substituted via a collapsible infusion bag. A volume-constant perfusion is performed.

System application: Safety of the system was proven in a large number of CABG operations on the beating as well as the cardioplegic-arrested heart. As it is wise to install an ECC-system rapidly if the patient is requiring resuscitation, the system is used for this indication. It has been shown that an adequate circulatory and pulmonary support is possible independent of cannulation site - femoro-femoral or RA-Ao.asc. The installation of the MECC-system is in this situation not fixed to specific localities. Because of standardization of the system it is ready to use in a very short time. The heparin coating renders prolonged support over several days (e.g. post-cardiotomy-syndrome) with reduced heparin administration possible. Likewise stabilization of critical patients during cardiologic interventions (PTCA) is possible. A further application option is as assist device in the operative treatment of thoracic aneurysms. Application of the minimized ECC-system for rewarming after accidental near drowning facilitates rapid correction of metabolic abnormalities. In addition the system can be kept in operation if a respiratory insufficiency after rewarming should arise. In patients with heparin-induced thrombocytopenia (HIT) Typ II the necessary intra-operative amount of hirudin can be reduced by using the uncoated MECC-system.

Conclusion: MECC is a safe and efficient system for multifunctional use including applications outside of the cardiac operating theatre.

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DEVELOPMENT OF AN ECMO PROGRAM—FROM LONG TERM CARDIOPULMONARY BYPASS TO INTERDISCIPLINARY COLLABORATION

Introduction: The establishment of an ECMO program at an university hospital requires close interdisciplinary collaboration. A full time presence of perfusionists during the conduct of ECMO will be difficult if the hospital buildings are distributed over a wide campus. Therefore the conduct of ECMO is only possible with continuous education of personnel which is unexperienced with perfusion concerns. To provide a system for both cardiac and neonatal (pulmonary) ECMO a circuit was developed which is markedly different from routine cardiopulmonary bypass. The option of suctioning or venting may be required during a cardiac indication but they are redundant for a pulmonary indication.

Methods: Experience in neonatal and paediatric routine and long term cardiopulmonary bypass and the parallel development of an neonatal ECMO program led to the development of a centrifugal (Biomedicus, Minneapolis, USA) based circuit with a range of long term ECMO silicon coil membrane oxygenators (Medtronic).

Results: Between July 2000 and April 2003 21 cardiac, pulmonary and adult cases were considered to require ECMO. In 16 cardiac cases ECMO was initiated due to postcardiotomy failure. Pulmonary ECMO was initiated in three cases. A complete change of the circuit was only performed due to thrombus formation in the circuit. Mechanical failure due to flow probe breakage (n = 1) could be performed without complications.

Discussion: A support of an ECMO program from perfusionists requires knowledge about long-term effects of extracorporeal systems which are beyond routine cardiopulmonary bypass. In contrast to short-term extracorporeal circulation problems often develops in the range of hours and can be solved with adequate preparation. Conduct of ECMO from non-perfusionist personnel requires continuous at least annual training and education and a supporting background from a perfusion department.

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DATA COMMUNICATION IN A PERFUSION TRAINING MODULE

**Purpose:** Nowadays simulators are playing an increasing part in the education. Not only in aviation (flight training) you can be without simulation. Simulators are more and more used for education and training as well as for emergency training in the sector of medicine. While the sectors of emergency medicine, of minimal invasive surgery and of anaesthesia have available high developed simulators, there are no or only few steps to simulate the extracorporeal circulation of a HLM in connection with hardware. The HLM-Hardware-Simulator increases the ability of the cardiovascular engineer to handle difficult situations.

**Method and results:** The simulator system consists of two main components, a heart lung machine and a control-PC. The PC is located in a separate surveillance room. The HLM is connected to a patient simulator. All the medical parameters and HLM device adjustments should be indicated on a monitor. Furthermore, the medical parameters of the artificial patient can be manipulated and you can influence the function of the HLM.

Real emergency situations like an oxygenator obstruction, a power cut, an obstruction of the arterial filter or bubble production are controlled with a touch screen monitor. Valves, which are driven by electric motors, are integrated in the hose system of the HLM. These electric motors obtain the signals by serial ports and measurement charts of the control-PC. This procedure enables also the simulation of an oxygenator obstruction. The updated medical parameters of the artificial patient are sent wireless by the HLM to the control-PC.

**Discussion:** The project is based on the “GREEN BOX”, which was first used on 22nd and 23rd November 2002 for the safety training at the symposium “Safety at the heart lung machine” at the FH Furtwangen, department Villingen—Schwenningen. Finally the feedback of the participants of the symposium at the FH Furtwangen has shown, that the simulation of incidents was a special experience for each person. Not only students and trainees but also cardiovascular engineers with experience should have the opportunity to practice with the hardware simulator.

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CASE REPORT: INFECTION OF AN ENDOLUMINAL STENT IN THE DESCENDING AORTA NECESSITATING EMERGENCY REPLACEMENT OF DESCENDING AORTA AND DISTAL AORTIC ARCH IN DEEP HYPOTHERMIC CIRCULATORY ARREST

Diagnosis: Aortic aneurysm in the presence of chronic type B dissection, post implantation of intra-aortic stent, highly suspected development of a mycotic aneurysm, post CABG x 2.

ECC Setup and Monitoring: In the, at our hospital routinely used, HL30 Heart-Lung-Machine (Jostra) a vacuum controlled active venous drainage by means of centrifugal pump was integrated. In addition a second arterial line containing a flow measurement probe was connected distal to the arterial filter. Arterial and venous blood gases were measured online (CDI 500) in the ECC circuit as well as online arterial blood gases in the femoral artery (Micro-tip-catheter, Paratrend). Cerebral saturation was monitored by means of infrared spectroscopy (INVOS), temperature measurements included bilateral tympanic, rectal and bladder.

Installation of ECC: After the administration of heparin (5000 I.E.), cannulae were introduced into the right subclavian artery (24Fr Baxter) and the right femoral vein (V172-28, Stöckert) with the patient in the supine position. The cannulae were then closed with a sealing plug. Following successful positioning of the patient in a right lateral position, the cannulae were connected to the ECC circuit tubing. Skin disinfection and sterile draping was performed. Surgical approach was through a posterolateral thoracotomy.

Management of ECC: At the start of ECC the temperature of the heater/cooler was set at 12°C. In the ensuing cooling phase 3000 ml of blood volume was removed from the system and stored in blood bags, hemodilution was continued down to a hemoglobin content of 3,8 g/dl. Cardioplegic solution was not administered. At an arterial blood temperature of 18°C, a bolus of 40 mmol KCL was given, this resulted in rapid cessation of cardiac electrical activity. After a cooling time of 40 minutes a tympanic temperature of 14,5°C was reached and circulatory arrest begun. Due to surgical reasons an antegrade cerebral perfusion was technically not possible. Subsequent to a circulatory arrest of 44 mins perfusion was restarted over the subclavian artery with a flow of 800 ml/min (arterial blood temp. 22°C) through the upper vascular region of the body up to and including the left common carotid artery. Following a further 55 minutes perfusion of the distal parts of the body was recommenced by means of the second arterial line over a lateral port of the thoracic part of the prothesis. While the two parts of the prothesis were surgically joined the patient was rewarmed briskly with the heater/cooler temperature set at 38,5°C. At an arterial blood temperature of 23°C spontaneous cardiac activity in the form of sinus rhythm recurred. In the rewarming period free plasma water was extracted by means of hemofilter and the patient received the blood removed during the cooling phase. Following a rewarming time of 80 minutes the patient was uneventfully weaned from ECC. Recovery was unproblematic for the patient; he was extubated 20 hours postoperatively. The patient displayed no neurological abnormalities and the cerebral ischaemia markers (S100, NSE) were at the upper end of the normal range.

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HARDWARE SIMULATOR OF THE CIRCULATION—A TRAINING MODEL FOR CARDIOVASCULAR ENGINEERING

At the University of Applied Sciences Furtwangen, Villingen-Schwenningen, Department of Medical Engineering the idea of developing a hardware-simulator of the circulation has existed for a long time.

**Purpose of the study:** The dream was to realize an artificial and multifunctional “patient” to work with medical devices. At the beginning of the project the main emphasis is on Cardiovascular Engineering. A device should be developed to serve as a simulator for a heart-lung-machine. The main aim of the project should be the support of students’ and cardiovascular engineers’ education and the possibility of analyzing and improving the behavior of trainees in rare extreme situations.

**Information about materials and methods:** The students tried to simulate the natural phenomenon of the circulation in the human body. It was and is not easy to build a circulation simulator with little money. So a cheap solution had to be found. Nearly all components used in the simulator are everyday items. Of course some devices had to be bought specifically, e.g. electrical and electronic components like step motors and the microcontroller.

The system can be used autonominously which means that the artificial patient has its own heart and a closed circulation. In the region of the simulator’s thorax two standard tubes for the heart-lung-machine are already prepared in the synthetic heart. So a extracorporeal circulation is possible.

At the computer terminal the trainer has different possibilities to influence the medical parameter of the “patient”. For example he can increase or decrease the total peripheral resistance, change the volume of “blood” or he can inject air bubbles into the circulation. Many extreme situations for the cardiovascular engineer can be simulated. At least the simulation will take place in a scenario which will be in a operation theatre with “real” doctors and assistants.

**Summary of results and the reached conclusion:** Even though the development of the project is not yet finished we can draw the conclusions that we realized more ideas than we expected and that we will reach our aim faster than we supposed. The presentation describes the development of the project from the beginning up to now and a look-out on the project’s future.

Please note our new home page, which will be updated regularly during the development period of the simulator: http://www.cardio-sim.de/.

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MINIMIZED HLM—IS LESS MORE? COR X® (CARDIOVENTION)—CLINICAL PRACTICE AND RESULTS

Introduction: Since 2002, Cardiovention has been offering a newly conceptualised complete system for extra corporeal circulation. The system’s primary components comprise a Power Base (a console including operation, monitoring, power supply, fixtures and a so-called Air Vac), as well as an oxygenator with tubing system.

The CORx was originally developed in order to provide an alternative to off-pump coronary surgery, and is intended specifically for use with beating heart under normothermic conditions. Significant features of the CorX include minimal priming volume all the way down to “zero prime”, very small tubing system and oxygenator surface areas, and all the advantages of a closed system with an option for continuous venous air elimination by means of the Air Vac. The Power Base is only half as large as a 4-pump HLM.

The Methodology and the Study: CORx was first used at the university clinic in Frankfurt in March 2002. The original tubing set was subjected to several modifications during the course of use. Heat management and myocardial protection were thus adapted to clinic-specific requirements. The console’s software was also improved in accordance with requests submitted by the users.

Results: The presentation will elucidate the differences between CORx and a conventional HLM, as well as the possibilities offered by CORx in daily clinical use, in a critical fashion. In addition to special handling of the system implemented at the university clinic in Frankfurt, utilisation of the autoplegia method in combination with Calafiore blood cardioplegia during use of the CORx will be presented as well. At the same time, initial results of a comparative study including 100 heart patients at the university clinic in Frankfurt will be presented, which compares the system’s clinical and economical parameters with use of a conventional HLM.

Discussion: Implementation of the CORx system will first require concrete agreement amongst heart surgeons, anaesthesiologists and cardio-technicians. Optimised use of the CorX can only be assured if the entire OR team interacts in close cooperation with one another. After more than 70 operations performed using the CORx, our experience indicates that the system can be utilised in a trouble-free fashion in coronary surgery after implementing certain modifications. Whether or not the system will be able to establish itself in the field of coronary surgery in Germany in addition to the conventional HLM, and which additional applications is may be used for, will be the subject matter of further clinical and economic evaluations.

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INVESTIGATION OF GASEOUS MICROEMBOLI GENERATION IN THE HEART-LUNG-MACHINE AND SUGGESTIONS HOW TO REDUCE THEM

Background: Air embolism is one of the most fatal complications of the extracorporeal circulation (ECC). A modern heart-lung-machine (HLM) has integrated safety features that reduce the risk of massive air infusion. However, the question arises whether the patient, in spite of using an arterial filter, is protected enough against gaseous microemboli (GMB).

Method: 45 adults undergoing different cardiac operations by means of ECC were included in this study. The microbubble activity in the extracorporeal system was continuously recorded and analyzed. We measured GMB with a two-channel ultrasonic bubble counter (UBC, HPmedica, Augsburg, Germany). To detect each source of microbubbles in the ECC, in each case we placed one sensor before the oxygenator. The second ultrasonic probe was placed either after the oxygenator or after the arterial filter. In 8 cases the sensor was positioned behind a novel device that continuously removes microbubbles during the ECC – the dynamic bubble trap (DBT, HPmedica, Augsburg, Germany). In each case of activity, we tried to identify the source of GMB.

Results: We observed microbubble activity during all 45 operations. As anticipated, we recorded the highest number of GMB during mitral valve operations, followed by aortic valve operations and CABG procedures. An open venous reservoir system generates much more GMB than a closed circuit. The usage of a cardiotomy reservoir with separation of sucker blood increases the number of generated GMB. Microbubbles generated in a filtered cardiotomy reservoir were very efficiently filtered through the oxygenator and/or the arterial filter. Microbubbles coming from the venous line were only insufficiently eliminated by the HLM.

Summary: Microbubbles were generated during each operation with the use of a heart-lung-machine. The best method to remove microbubbles from blood is to use the dynamic bubble trap (DBT). However, this device has also some disadvantages. By the optimization of the tubing system, minor changes in surgical techniques and adherence to certain rules the perfusionist can drastically reduce the number of microbubbles generated in the extracorporeal circulation.

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VALVE INSUFFICIENCY AT ASSIST DEVICES AND THERE POSSIBLE PATHOGENESIS

Background: Implantable left ventricular assist devices (LVAD) have been used as bridge to transplant with excellent clinical results. The long-term use of these devices as alternative to transplant is limited by device-specific complications. Progressive device failure of the TCI HeartMate due to regurgitation of the inflow conduit valve is a common problem after extended periods of mechanical support.

Methods: The Heartmate VE was implanted as bridge to transplantation in 9 patients. After explantation of the LVAD the biological valves of the inflow and outflow conduit were examined. The mean support time was 145±92 days (range:25-272 days). In addition, two new TCI inflow conduits were tested in vitro in an accelerated pulsatile valve tester.

Results: Eight patients could be successfully bridged to heart transplantation, one patient died due to an acute rupture of the aortic anastomosis after 27 days. Five of the nine inflow conduit valves showed severe destruction, which was associated with clinical signs of device failure in 3 cases. Systolic pressure measured within the LVAD reached 400 mmHg. The pulsatile valve tester revealed dehiscence of the stent sutures and tears of the biological valves even after 17 million cycles according to a support time of 118 days.

Conclusions: Even though the excellent clinical outcome of our patients using the Heartmate VE progressive device failure due to the destruction of the inflow conduit valves has to be expected in the majority of patients after six months of mechanical support. This early damage may be due to the extremely increased systolic pressure generated by the blood pump.

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DEVELOPING A SYSTEM FOR KEEPING THE THORAX OPEN (STERNAL RETRACTOR STENT)

Problem: In patients with low cardiac output there is sometimes the need to delay sternal closure post operatively. Various technical procedures are available for retracting and stabilizing the sternal halves and keeping them apart. Many authors use plastic syringes as Stents, but with this method the thorax is quite instable and altering the positioning of the patient in ICU is very limited, if at all possible. Dislocation of these Stents can lead to myocardial injury.

Aim and Objective: The aim is to stabilize the open thorax using a stenting system so that nursing and positioning of the patient can be carried out safely. The system should also fulfill other criteria, such as allowing an adjustment in width at “second look operation” whilst the system is in situ, i.e. the distance between the sternal halves can be increased or decreased without having to remove the stents.

The system should also be bio-compatible, easily placed, easy to use, stable, allow fixation, be simple to clean and re-sterilise, and radio-opaque.

Solution: A stainless steel thorax stent was designed and produced. The sternal halves plus the sternal stent together form a stable unit, the thorax is sealed with a sterile foil membrane. The foil membrane allows fast and easy access to the thorax in cases of hemorrhage, etc. The variable adjustment option allows the distance between the sternal edges to be decreased as necessary during second-look procedures, enabling closure of the thorax after the minimal setting has been used.

Discussion: This newly developed system has so far been used in 90 patients with low cardiac output., The patients were positioned and nursed without any problems. We have seen only one dislocation (which occurred at the early stage of use).

This sternal stent system now has a permanent place in patients with open thorax in our clinic.

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Transportation of patients on biventricular assist devices (BVADs) remains a challenge for the heart team. Type of cardiovascular support, type of vehicle, transport time and patient medical history are important factors when considering interhospital transfer. We report on the first successful intercontinental transport by long haul ambulance flight of a patient on an Abiomed BVS 5000 BVAD from Singapore to Berlin, Germany.

A 59-year-old male European tourist was admitted to hospital in Singapore. Fulminant myocarditis was diagnosed and an Abiomed BVS 5000 was implanted as an LVAD. Six days later right ventricular failure requiring RVAD implantation developed. Ten days after the first operation the patient was transferred back to Europe by ambulance aircraft. The patient was mechanically ventilated and sedated. Transport from the Singapore hospital to the airport was performed with an Abiomed 5000t (transport) console. Transfer from the ambulance into the aircraft (and vice versa) was performed using a modified hand pump from the BerlinHeart VAD. Inside the aircraft, the driving lines were connected to a stationary Abiomed BVS 5000i console. For transportation from Berlin airport to the Deutsches Herzzentrum, the patient was connected to an Abiomed BVS 5000i console inside the ambulance.

The 15.5-hr flight was performed at an altitude of 40,000 feet with a cabin pressure equivalent to 8,000 feet. Total transport time was 19 hrs with one stopover for refueling. At cruising altitude, pump flow decreased to 4 l/min, making an increase of norepinephrine dosage from 0.16 to 0.22 μg/kg BW/min necessary. At sea level, pump flow increased to up to 5 l/min and norepinephrine dosage decreased to 0.16 μg/kg BW/min. ACT was maintained between 160 and 180 sec. Due to continuous bleeding (100 to 150 ml/h) from the right chest drain and because of the dry air inside the aircraft, volume replacement included 6 units of packed red cells, 4 units of fresh frozen plasma and 6 liters of crystalloid infusion solution. After arriving in Berlin, the patient was switched to the BerlinHeart extracorporeal BVAD and is now awaiting heart transplantation.

Intercontinental transportation of a critically ill patient on an Abiomed BVS 5000 BVAD can be safely performed. Experienced team members, meticulous preparation and anticipation of possible events during transportation are necessary for successful patient transfer.

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INTERCONTINENTAL BVAD TRANSPORT BY LONG HAUL AMBULANCE FLIGHT

ABSTRACTS
ANESTHESIA FOR PEDIATRIC CARDIAC SURGERY WITH DEEP HYPOTHERMIA

**Introduction:** The history of myocardial preservation begins with hypothermia, first mentioned as a therapeutic option 4000 BC by the Egyptians. The introduction of extracorporeal circulation (ECC) in the 1950s provided an alternate means of inducing hypothermia. In pediatric cardiac surgery with sometimes time consuming complex repair hypothermia provides more time for the surgeon and a longer safe operating period. But hypothermia has not only benefits and the specific risks despite all technical advances must be considered by the anesthesiologist.

**Hypothermia and the heart:** Low temperatures reduce the metabolic rate of the heart. At 17°C the myocardial oxygen consumption is only 12% of that at 37°C. Low temperatures also protect the heart from so called “calcium paradox” due to massive influx of Ca2+ on reperfusion with a Ca2+ containing medium.

**Hypothermia and the brain:** The impact of deep hypothermic circulatory arrest on the neuropsychological outcome remains controversial. However, there is general agreement that despite the great advantages of bypass as well as anesthesiological or surgical technique, there is a higher incidence of detectable neurological deficits in young children undergoing cardiac surgery than the normal population.

**Hypothermia and major organs:** Low cardiac output as well as low-flow during ECC will result in inadequate supply of vital substrate to tissues leading to anaerobic metabolism and increasing metabolic acidosis. Measurements of blood gases are revealing increasing base deficits and decreasing of bicarbonate levels. The blood lactate concentration is a simple monitoring parameter and is subsequently increasing during ischemic periods.

**Management during hypothermic bypass:** Due to temperature depending increasing systemic vascular resistance and therefore increasing blood pressure the calculated bypass-flow during hypothermia is often reduced. This could increase the time of cooling and rewarming and could be a reason for the increase of lactate production. The technique we use is to lower the vascular resistance with phentolamine (2-3 μg/kg/min⁻¹) and/or nitroprusside-natrium (1 μg/kg/min⁻¹) followed by increasing the bypass-flow from 100% to 120% of the initial calculated flow rate. The blood pressure is kept between 25-35 mmHg depending on the body weight of the children (high-flow, low-pressure bypass). Deep opiate anesthesia with high-dose fentanyl is used for anesthesia to prevent vasoconstriction through circulating catecholamines. As a result we could see in 94% of our patients normal lactate values compared to the initial data and cooling and rewarming is mostly associated with a low Δt.

**Conclusion:** Low-pressure, high-flow bypass could be an interesting method in ECC with deep hypothermia.

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OPEN HEART SURGERY USING A MINIMIZED CARDIOPULMONARY BYPASS SYSTEM (CARDIOVENTION): TECHNICAL ASPECTS AND FIRST CLINICAL RESULTS

**Purpose:** Cardiac surgery with cardiopulmonary bypass is known to be associated with marked inflammatory response, deteriorated coagulation, organ dysfunction and neurological complications. Nevertheless, cardiopulmonary bypass is unavoidable in complex open-heart surgery. Innovative minimalized heart lung machines, which provide a decreased foreign surface area and less hemodilution are currently available for hemodynamic support during coronary artery surgery. We evaluated the potential use of one system for open heart surgery.

**Materials and Methods:** The CARDIOVENTION cardiopulmonary bypass system, was modified by integration of a left ventricular vent, bubble traps and a cardioplegia line. This enabled us to perform even complex procedures with this minimalized setup (no heat exchanger, no arterial filter). Short perfusion lines reduced the foreign surface area below 1.4 m². Reduction of hemodilution volume was achieved by retrograde priming of the system with blood after aortic cannulation. This resulted in a decrease of the hemodilution volume below 0.2 liter. Aprotinin was given in only 3 cases. Between April and December 2002 a total of 32 patients underwent open heart surgery with the described setup.

**Results:** The handling of the new system by the perfusionists required more attention to hemodynamic changes of the patients as well as system performance but was uncomplicated in all patients. The normothermic approach was successful with a stable rectal temperature during surgery (36.3±0.1 preop. vs. 35.6±0.1 postop.). Mean bypass time (101±5 min) as well as aortic cross-clamp time (75±4 min) were within standard range. Recovery was completely uneventful in all patients. Mechanical ventilation was necessary for 19.1±4.9 hours after surgery. The mean stay on the ICU was 2.3±0.4 days and the mean total hospital stay was 13.4±0.9 days. Serum creatinine levels (baseline 0.9±0.1 mg/dl vs. 24 hours postop.: 1.0±0.1 mg/dl) remained stable. Intraoperative autotransfusion requirements were moderate and only 11 patients (34%) needed cell saver blood with a mean amount of 246±131 ml. The mean blood loss during the observation period was low (620 + 350 ml). A total of 15 patients (47%) did not need any transfusion and overall transfusion requirements were modest (PBC 512 ml±124 ml, FFP 564±152 ml). Administration of thrombocytes was necessary in only 2 patients (2 units/patient). The decrease of hemoglobin in those patients who did not receive PBC was moderate from baseline 14.7±0.2 to 11.5±0.3 g/dl after surgery (24 hours). Myocardial protection was successful, displayed by the absence of myocardial infarction signs in the postoperative ECG as well as in postoperative creatine kinase levels (CK/CKMB baseline: 37.8/1.0±6.5/1.0 U/l vs. CK/CKMB 24 hours postoperatively: 453.0/25.1±88.4/3.4 U/l). Administration of norepinephrine (12±2 mg/24 hours) was necessary in only 4 patients (13%) indicating an overall low systemic inflammatory response. No adverse neurologic events were seen in the cohort.

**Conclusions:** The modified CARDIOVENTION system provides safe circulatory support in open-heart surgery with only minor modifications to the standard system setup. Systemic inflammatory response and transfusion requirements were found to be low in these patients.

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The University Hospital Maastricht started two years ago with a new program for aortic surgery in which the technique of professor M. Jacobs was adapted. We use a multidisciplinary approach to provide an optimal monitoring of the patient’s status, in particular the neurophysiological aspects.

The surgery types can be divided in aortic arch replacement, thoracic abdominal aneurysm surgery and total aorta replacement. The key element is the extensive neurophysiological monitoring during surgery.

During aortic arch replacements the cerebral flow by the extracorporeal system is closely monitored by transcranial doppler and EEG to provide additional information about the efficacy of perfusion.

In case of thoracoabdominal surgery the emphasis lies on spinal cord preservation for which the motor evoked potentials are monitored for an early warning of ischemia. This in combination with selective extracorporeal organ perfusion.

The total aorta replacement forced us to develop a specific extracorporeal system to be able to switch between left-left bypass and total bypass with low and full heparinization.

One of the specific elements of our approach is the very limited use of hypothermia during these procedures and the absence of circulatory arrest for the cerebrum.

In this presentation an overview will be presented of the surgical procedures and the extracorporeal solution for these challenging problems.

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CONTROL OF AN INTRA-AORTIC COUNTERPULSATION PUMP VIA A TEMPORARY PACEMAKER CONNECTED TO AN INTERFACE WHICH PRODUCES VIRTUAL INTRACARDIAC ECGs

Background: Particularly during OPCAB Surgery the possibility to achieve an adequate ECG signal for counterpulsation is often limited. Manipulation of the heart disturbs the pressure-trigger signal and the same is true for the ECG-trigger signal due to a specific problem coming from the vector characteristics of the ECG signal. To correctly provide counterpulsation with very tightly controlled parameters based on heart function, the Intra-aortic Balloon Pump requires the best possible disturbance-free trigger signal.

Methods: Production of a virtual ECG signal is achieved through an interface based on ventricular sensing of a temporary pacemaker (Fig. 1).

Results: Practically noise-free counterpulsation triggering was made possible by achievement of a clean, strong and stable synchronous R-wave ECG trigger (Fig. 2).

These advantages are particularly obvious during OPCAB Surgery and were proven in practice by use in more than 80 clinical patients.

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