

Abstracts

REDUCTION OF MICROEMBOLI COUNT IN THE PRIMING FLUID OF CPB CIRCUITS

Background: Microemboli can cause cognitive dysfunction in heart surgery patients. Prebypass filtration eliminates particle and gaseous contaminations (microemboli) from the CPB priming fluid. This study was carried out to determine the microembolic capacity of the CPB priming fluid as well as to check the efficiency of a 0.2 μm prebypass filter (Pall Biomedizin, Dreieich) in eliminating microemboli from 0.1 to 0.5 μm .

Method: Twelve CPB systems were tested in two groups. A highly sensitive particle counter, sensitive to microemboli from 0.1 to 0.5 μm , determined the number of microemboli per cm^3 priming fluid. In control group A, infusion solution was examined before filling of the CPB, in group B, CPB systems with microporous membrane capillary oxygenators ($n = 5$), and in group C, CPB systems without oxygenators ($n = 7$) were examined.

Results: In the comparison of control group A with groups B and C, a higher number of microemboli in groups B and C for the categories 0.2 μm , 0.5 μm and 0.8 μm were found ($p < .05$). Group C systems had, as compared to group B systems, a higher number of microemboli in the categories 1.5 μm and 3 μm ($p < .05$). Microemboli in the category 0.2 μm or larger could be completely eliminated by a prebypass filter over 2 min with a CPB flow of 5 L/min. Microemboli in the category smaller than 0.2 μm could be considerably reduced in number.

Discussion: Microemboli around 0.1 μm in size mainly originate from the infusion solution that is used to fill the CPB. Microemboli in the categories 0.2 μm , 0.5 μm and 0.8 μm mainly originate from the CPB system. In systems without oxygenators, a slightly higher number of microemboli in the categories 1.5 μm and 3 μm could indicate a filter effect by the membrane oxygenators. The investigated 0.2 μm prebypass filter is an effective means of eliminating microemboli from the filled CPB system before hooking it up to patients.

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NEW ARTERIAL FILTER DESIGN

Background: Embolic complications that have their origin in the extracorporeal system (ECS) lead to various pronounced complications. Fundamentally, two causes differentiate embolic complications: (1) air emboli and (2) particle emboli. For further reduction of air embolic complications, a new arterial filter was conceived.

Experimental: Two conventional arterial filters were compared with the new filter design. In a circuit filled with Ringer's lactate, the roller pump transported 4.5 l/min from a level of 500 mL in the cardiectomy reservoir, the fluid through the respective arterial filter and back into the cardiectomy reservoir. An additional smaller roller pump pumped air regulated in five steps starting at 40 mL/min and building up to 1,280 mL/min via a Luer connection into the circuit. The Luer connection was on the suction side of the larger roller pump. An ultrasound (Hatteland CMD 10) 15 cm behind the filter measured the quantity of air that passed through the filter, and not via the open Luer connection in the inlet area of the filters. The CMD 10 gives out voltage via the mean output interface, which corresponds to the chronological mean value of the bubbles' size and number. The output voltage was measured and recorded continually by a digital PC storage oscilloscope (Velleman PCS 64 I). The mean values for the obtained values (8 bit by 100 samples per second) were calculated and processed in MS Excel. At the beginning of each measurement an automatic zeroing was carried out in order to have baseline values. As a result, each measurement produced a plot, which was proportional to the bubble size and number.

Method: Two models from each of the three filters were measured one after the other and the mean value for each type was defined. For the conventional filters, type A is an arterial filter with a vertical inlet and horizontal outlet, and type B is a filter with horizontal inlet and vertical outlet. Type C, the new filter design, has a two-chamber system. The filter has a horizontal outlet into the air elimination chamber where the air can be centered and eliminated without it coming into direct contact with the actual filter medium. Only then can the fluid flow into the second chamber—the so-called particle elimination chamber, where the fluid enters the filter medium moving from inside to outside and then leaves the filter through the outlet connector.

Results: The new filter design clearly has a better air elimination capability than either of the conventional filters. The mean values of the measured voltage were respectively 0.2545V for type A, 0.1808V for type B and 0.0954V for type C. (The lower the voltage, the less air there is).

Conclusion: In comparison to the two conventional filters better air separation can be achieved in filter type C because of the special fluid dynamics in the air elimination chamber.

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ESTIMATION OF MICROBUBBLE SIZE DISTRIBUTION IN THE EXTRACORPOREAL CIRCULATION WITH ULTRASOUND

Background: In many medical applications the recognition of microbubbles in fluid mediums is of great practical interest. For example, microbubbles are constantly formed by the circulatory system during the use of CPB in open-heart surgery operations. Their number and size depends on current operational procedures and the necessary manipulations to the CPB. Should too many and too large bubbles get into the blood circulatory system of the patient serious complications (emboli) could result.

Method: The measuring procedure is based on scattering specifically reflections of ultrasound waves on microgasbubbles. The amplitude of the reflected impulses is in a wide size area proportional to the cross section of the bubbles. To determine the size only the Doppler signals are digitalized and evaluated. The signal parts that are not scattered also penetrate the opposing tube wall and hit a special reflector. These echoes are also recorded by the detector. They contain, among other things, about the acoustic properties of the tube material. As a result it is possible to carry out measurements independent of the tubing material used. The calibration of the measuring system is completed with a specially developed bubble generator. The bubbles are injected individually into the tube system and recorded using a microscope camera system. A computer evaluates the size distribution. The bubbles were also simultaneously registered by the measuring system and finally compared with the system parameters. The calibration across the entire measurement range took place through the change of the middle bubble size at the generator.

Results: The two channel measuring system is able to determine microbubbles in the size range 10 to 250 μm in flowing fluids. The sensors can be very easily coupled onto the tube system of the CPB by sleeves and without direct blood contact. The number and size of the recorded bubbles are illustrated in the form of histograms (number versus diameter, cross section, or volume) and as a chronological plot (number or concentration versus time interval).

Discussion: The particular advantage of the measuring system lies in its high sensitivity. Even the smallest microbubbles up to 10 μm in diameter can be detected in every case. The simultaneous measurement with the two channels allows, amongst other things, differential measurements, e.g., the assessment of arterial filters.

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IMPROVED METHODS OF MEASURING GASEOUS MICROBUBBLES DURING EXTRACORPOREAL CIRCULATION

Background: A measurement of the number and size of gaseous microbubbles in the arterial line of extracorporeal circulation is important for assurance of perfusion quality. In order to carry this out more precisely, new evaluation algorithms were developed.

Method: An ultrasound method is employed to measure gaseous microbubbles. An ultrasound wave is scattered at the bubbles found in the blood. The resulting Doppler signal is evaluated to ascertain the bubble size. Our investigations have shown that the quality of the ultrasound signal is strongly influenced by disturbances that regularly occur in the operating theatre, such as high frequency and electromagnetic disruptions or electrocoagulation. A high number of bubbles in the measuring range can also lead to undesired results.

Results: Various evaluation algorithms were developed and tested. The observed algorithms evaluate the signal in both time and frequency ranges. They reduce the influence of disruption on the exactness of the bubble detection. The online data were registered during the entire operation and finally evaluated with different algorithms. In this way an optimal algorithm was ascertained.

Discussion: This evaluation method was implemented in a two-channel ultrasound-measuring device used in a clinical study. This method has led to a considerable increase in measurement accuracy and reliability.

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MICROBUBBLES IN BYPASS AND VALVE OPERATIONS AND THEIR ELIMINATION

Background: Air microbubbles form largely unnoticed during cardiosurgical operations in the circulatory system and can lead to serious problems. Through the use of a dynamic air trap (DBT) these microbubbles can be effectively eliminated from the blood flowing through the CPB. A comparison of microbubble formation during aortic coronary vein bypass (ACVB) and aortic valve replacement (AKE) operations is discussed.

Method: The DBT functions according to the following principle. When blood flows through the DBT, which is situated between the arterial filter (AF) and the arterial cannula, it is set in rotation. The microbubbles collect in the central blood stream, which is then taken out of the DBT during discharge and returned to the cardiectomy reservoir. Two studies were carried out: 50 patients (25 with DBT, 25 with placebo) who underwent an ACVB operation and 41 patients (22 with DBT, 19 with placebo) who underwent an AKE operation were investigated. Among other things, the number of microbubbles was ascertained immediately before and after the DBT by a two-channel ultrasound Doppler measuring device.

Results: It was found that the number of air microbubbles after the AF in patients who had undergone an ACVB operation was on average 3990 (range from 415–16,442). The DBT clearly reduced the microbubbles; the average value lay around 520 (range from 77–1,397) and larger microbubbles ($>20\ \mu\text{m}$) in particular were greatly reduced. In patients who had undergone an AKE operation, the number of microbubbles was considerably higher. On average 14,823 bubbles were measured before the DBT (range from 2240–35,502), after the DBT 4,346 (range from 701–9374).

Discussion: These results show that a considerable reduction in microbubbles out of the arterial blood is possible, which is a positive contribution to the quality of perfusion.

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HOW CAN THE PERFUSIONIST INFLUENCE MICROBUBBLE FORMATION DURING CARDIOPULMONARY BYPASS?

Background: Either physical factors (pressure, velocity, or temperature of the circulating blood) are caused to change or air is sucked in (vent, cardiectomy suction, leaking cannulae) as a result of microbubble formation during cardiopulmonary bypass (CPB). The perfusionist is able to influence almost all of these causes.

Method: During many hundreds of surgical interventions with CPB microbubbles were measured predominantly in the arterial line by means of Doppler ultrasound technology. The main causes of microbubble formation and how the perfusionist could reduce them have been examined.

Results: Despite carefully de-airing the HLM set, some air always remains in the system. This air can considerably be reduced with a short CO₂ irrigation. Every sudden change in pump flow (start/stop of the HLM) results in short-term pressure changes, which are the reason for the formation of microbubbles.

When a fluid (drugs, infusion, blood) is administered, the position and the velocity of the infusion are of great importance. A direct administration into the venous reservoir may result in a microbubble exposure ten times higher than that of an infusion into the filtered cardiectomy reservoir. Every incautious blood draw may expose the patient to many hundreds of microbubbles.

The perfusionist can also successfully influence the results caused by the air sucked in. In an open system it is important to keep the level of the blood in the hard shell reservoir as high as possible. In a closed system a high blood level in the cardiectomy reservoir is very advantageous. An open purge line from the arterial filter to the cardiectomy reservoir and the opening of the venous bag often contributes to a reduction of microbubbles. In general it can be said that when the blood level in the cardiectomy reservoir or in the combined venous reservoir reaches a minimum limit (usually 200–300 ml), the number of microbubbles increases rapidly.

Conclusion: In addition to technical measures (e.g., dynamic bubble trap, DBT), there are possibilities enabling the perfusionist to diminish the formation of microbubbles and to reduce the number of already existing microbubbles only by adjusting his or her handling of the HLM.

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USE OF THE HLM IN EXTRACARDIAL TUMOR SURGERY; CASES FROM A SINGLE CENTER AS WELL AS THE CURRENT STATE OF THE LITERATURE

Background: Since the clinical introduction of extracorporeal circulation (ECC) in 1953, operations on the open heart, the aorta and the coronary arteries have become standardized routine operations. In addition to an isolated perfusion of extremities or organ systems as a second circulatory system, the ECC plays an increasing role in oncological operations. For a long time tumors intruding into large blood vessels or which had cardiac or pulmonary vascular involvement were considered inoperable because of the necessary interruption of the blood stream. Today, however, a resection of these tumours through the use of an ECC is possible in certain cases.

Method: As an example, we present three case reports and the intraoperative procedure. They concern a sarcoma of the A. pulmonalis, a thyroid tumor with intrusion into the V. cava superior and the right atrium and an advanced kidney cell carcinoma with tumour thrombus right into the A. pulmonalis. In these cases, prolonging of survival times and cures were achieved.

Results: In the literature, resection with the aid of the ECC is described as the preferred therapy in addition to the establishment of a hypothermic circulatory system arrest by using ECC for resection of retroperitoneal tumors with intrusion into the V. cava inferior, in particular for the kidney cell carcinoma with tumour thrombus into the V. cava inferior. Five-year survival rates of 50% not only in our own patients but also in the literature confirm this therapy approach to be curative. Both long-term survival rates and, according to several investigations, the arterial 20 µm filter, which represents an effective barrier to tumor cells, counteract possible tumor cell dissemination. However, the general immune suppression should be taken into account after operations with ECC, particularly with malignant tumors. Thus, no survival advantage could be shown for an extended radical resection of various other tumors with the aid of the ECC.

Conclusion: Altogether cures and clearly prolonged survival times after resection of tumors with the aid of the ECC that were previously considered to be inoperable demonstrate the benefit of this aggressive therapy in certain tumors. The operation with ECC for advanced kidney cell tumors is by now standard. Interdisciplinary cooperation in these cases is, however, indispensable.

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HYPERTHERMIC ISOLATED LIMB PERFUSION WITH TUMOUR NECROSIS FACTOR AND MELPHALAN: OPERATION PROCEDURE AND MANIPULATION OF THE HLM IN AN ARM PERFUSION

Background: Regional chemotherapy with isolated limb perfusion (ILP) was carried out clinically for the first time at Tulane University, New Orleans. Highly dosed cytostatica without toxic side effects on the whole organism can be regionally applied through the isolation of the limb's circulation via an HLM. In 1975 at the Surgical University Clinic, Erlangen, ILP was carried out for the first time in Germany. Since then more than 600 perfusions have taken place. The example of an arm perfusion is used to demonstrate the operation procedure and perfusion:

Methods: A 71-year-old patient had several coarse nodal metastases of a malignant melanoma on the left forearm and hand beginning to ulcerate. Primary tumor removal on the left palm in 1999, and thereafter, five excisions due to relapses on the hand and forearm with damage to the median nerve at a nonlocal clinic. Metastases were removed from the stomach wall and the back (stage IV). Palliative perfusion of the left arm was because of nonresectable lesions. Because of the size and good vascularization of the metastasis, perfusion with tumor necrosis factor (TNF) and melphalan was performed.

Setting-up the HLM. A modified children's set of type Lilliput 1 was used (Sorin Biomedica). In place of an arterial filter, a second heat exchange unit of type CSC 14 was used. An option for the addition of the cytostatic after the filters (arterial line), for the application of medication (venous crus) as well as for the drainage of contaminated blood for disposal was installed. Four temperature probes were placed: forearm (subcutaneous), two different positions, venous line (coming from the patient), and an arterial line after the second heat exchange unit. Line pressure measurement was direct on the arterial catheter. A vent line to suck up loss was installed. The priming consisted of 300 mL Ringer's solution with 5000 IE heparin. 3000 mL MakroDEX® was used as a flush solution for removing the medication from the vessel bed.

Procedure: The operation was carried out under general narcosis. A temperature probe was placed subcutaneously near to each tumor in the forearm. The forearm was wrapped in an external heating blanket (41°C). After exposure of the A and V brachialis, the collateral vessels were clamped. After systematic heparinization (125 IE/kg) the vessels were unclamped, fitted with cannulas, and connected to the HLM. The biggest cannula possible here guarantees minimal pressure gradients and optimal backflow. Successive increase of the HLM flow to 300–350 mL/min taking into account line pressure and backflow was implemented. A pressure gradient to the systematic mean pressure (10–15 mmHg) to the arterial line pressure prevents exchange with the circulatory system. A pressure sleeve (300 mmHg) was fitted onto the upper arm for the occlusion of collateral circulations and clamping of venous backflow out of the limb. To prevent leakage, a protein marked with radionuclide (99m-Tc-albumen) was put into the perfusion circulatory system and leakage rate registered via a gamma camera positioned above the heart. When using TNF a nuclear medical leak control, which may have a maximum value of 5–10%, is obligatory due to the toxicity of the substance. Other basic information: Control of the perfusion volume, haematocrit >15%, pO₂ > 300 mmHg, as well as balanced electrolytes. At a tissue temperature of 38° 1 mg fractionated TNF was injected into the arterial crus. After 30 min Melphalan was applied via a perfusor over 20 min into the arterial crus. The subcutaneous tissue temperature, particularly on the arm, may not go over 40° when using TNF. Ninety min after administration of TNF, the vessel bed was flushed out with 3 L of makroDEX by directing the venous discharge into a special canister for removal. The perfusion was ended as soon as clear flush fluid appeared in the venous crus. After release of the pressure sleeve from the vessels the cannula were removed, the vessels stitched, and

the circulatory system reopened. When dismantling the HLM and when handling the perfusate, care should be taken to use protective clothing and eye protection.

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HEART SURGERY OPERATIONS IN PATIENTS WITH DIAGNOSED BUT SURGICALLY NOT TREATED TUMOUR DISEASE: OPERATIVE RESULTS AND MEDIUM-TERM FOLLOW-UP

Background: With an increase in the average age of patients referred for heart surgery operations, the increasing co-morbidity rate plays a decisive role in the influence of perioperative results as do the medium and long-term follow-ups. Patients with malignant diseases are transferred to heart surgery operations not only because of urgent but also elective indications. According to how the risks are weighed, either the heart or the tumor surgical operation is given priority.

Method: We will report on the perioperative results as well as the medium term follow up in patients who were prioritized because of vital indication of heart surgery, and who were known to have malignant tumors, which had not been surgically treated. Starting in 1996 up until 04/2001, 49 patients with extracorporeal circulation were operated on in this clinical constellation.

Table 1.

	1996	1997	1998	1999	2000	04/2000	04/2001
Tumor	6	10	11	5	10	7	49
Age	65.0 ± 8.3	68.4 ± 5.6	69.9 ± 6.3	66.8 ± 3.2	68.0 ± 4.8	67.7 ± 9.8	68.1 ± 7.7
m/f	4/2	9/1	8/3	3/2	8/2	4/3	36/13
Bypass	6	8	7	5	9	4	39
Vitien	0	3	4	0	2	3	12

Results: Perioperative complications occurred in 10% of patients; bleeding and cardiac or multiple organ systems failure were most common. The perioperative mortality rate was 4% (n = 2), all other patients left the clinic for rehabilitation. The medium term follow-up (0.5–5 years) took place through questionnaires to the patients and the supervising GP. In addition to the survival rate, the development of cardiac and tumour associated symptoms as well as the quality of life was evaluated. The reply rate for doctors as well as patients was about 80%.

Discussion: Postoperatively four deaths were observed (two tumor associated and two attributable to cardiac causes). An acceleration of the tumor disease through the heart operation could not be observed. The careful selection of these critically ill patients allows good perioperative results, whereby the order of the surgical measures should be checked. In the heart surgical follow up the general prognosis of the disease is, however, more greatly influenced by the tumor-associated semiotics than the cardiac semiotics.

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EVALUATION OF THE BUBBLE RETENTION OF ARTERIAL BLOOD FILTERS

Background: A major problem of extracorporeal circulation (ECC) is the occurrence of solid and gaseous form emboli. Blood filters in the arterial crus should filter out these emboli from the blood stream. At the same time these filters are themselves a risk because they increase the extracorporeal volume and the blood contact surface. Because of this, reliable verification of its usefulness is required. The ability to retain microbubbles plays an important role.

Material and Method: An ECC circuit was simulated with hard-shell reservoir, centrifugal pump, and tube material. The patient was represented as flow resistance. Finally, the system was filled with 6% hemofusin and vented according to manufacturer's instructions. The bubbles were created through the addition of carbonated mineral water via an infusion injection pump. In preliminary tests a suitable quantity was determined. The size distribution of the microemboli before and after the filter was registered with a bubble-measuring device according to the ultrasound principle. The procedure is based on the phenomenon that (ultra) sound waves are scattered on small gas bubbles. Two ultrasound transducers were pressed around the tube. They emitted and detected the waves' impulses. As a result of the sound waves reflected off the bubbles their size and number can be determined and presented as a histogram. The duration of measurement took 15 min each time; flow speed and pressure drop across the filter were held constant.

Results and Discussion: The danger of an air embolism increases with the size of the microbubbles that can pass the filter. To determine the quality of a filter, it must not only be judged by its quantitative performance, but also by the bubble size that cannot pass through the filter to the patient. This passage boundary is not identical with the pore size, but is determined by the filter design, particularly the construction of the ventilation component.

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MEASUREMENT AND CORRELATION OF MICROBUBBLES IN THE EXTRACORPOREAL SYSTEM

Background: Blood oxygenation and tempering during extracorporeal circulation are frequently seen as source of microbubbles. This paper reports on their measurement and evaluation on the components of heart-lung machines (HLM) under simulation of defined environmental conditions. Blood tempering takes place with a heat exchange unit (HEU) on whose metal interface energy transfer out of tempered water results. For the formation of microbubbles, corresponding to a phase change of the partially dissolved gas, the temperature gradient T of the heat exchange unit interface seems to be decisive. Microbubbles by blood oxygenation in the membrane oxygenator are expected by a high transmembranous partial pressure gradient.

Material and Methods: The fundamental construction corresponds to that of a routine extracorporeal circuit. On the HLM SIIITM (Stöckert®) a plate membrane oxygenator (PMO) Cobe CML DuoTM (Cobe®) with integrated HEU was installed. The HEU was thereby built so far forward that it was not possible to place the US probes between it and the oxygenator, in order to enable a detailed statement on each of the components. An arteriovenous loop with integrated arterial 21 μm filter (Cobe SentryTM) was filled with 1.0 l electrolyte solution and 0.5l gelafundin. These result in hydrodynamic properties comparable with blood. The environmental conditions that were to be simulated were viewed over and above the physiologically reasonable limits: Flows of 0.5–4.5 L/min and a pO_2 range of 156–700 mmHg were simulated on the HEU. Simultaneously, the emitted microbubbles were registered at temperatures of 10–40°. The evaluation of the PMO took place analogously—the transmembranous pO_2 gradient was only drawn upon here. Furthermore, the flow was modulated pulsatilely to analyze bubble behavior at different pulse frequencies. Two ultrasound probes with a Farbdoppler multidop X-4TM (DWL®) were used for detecting the emitted microbubbles and were attached directly after the HEU and the PMO. All HITS (high-intensity transitory signals) that could be clearly differentiated from solid emboli were evaluated [1]. A recording was taken over a period of 5 minutes each time and the mean value calculated there from.

Results: The emission of microbubbles at the HEU shows clear temperature dependency so that under 30°C a strong increase in HITS resulted. A value of over 50 HITS/min can be reached with this temperature. With a $\text{pO}_2 > 300$ mmHg an increase in microbubbles can be noted. A small increase of 3 HITS/min in HITS intensity is shown at the PMO with a transmembranous pO_2 gradient from 350 mmHg onward. The investigation of the dependency on the flow shows a simple proportionality of about 4 HITS/l min^{-1} . With pulsatile modulation of the flow, an increase of 6 HITS/l min^{-1} from 60 bpm can be noted.

Discussion: The occurrence of postoperative cerebral ischemias after treatment with ECC is given as 2–8%. [2&rsqb. Thereby a direct correlation between the intensity of the microbubbles and the psychoneurological defects is produced [3]. In our paper, a strong temperature influence on microbubble activity is observed. The associated formation of bubbles through the reduction of gas solution capacity at low temperatures is particularly visible in hyperthermia at the heat exchange unit. A higher emissions rate exists fundamentally for microbubbles in pulsatile perfusion, which increases very strongly through negative pressure peaks on the oxygenator membrane. This occurrence is controllable through use of a nonpulsatile base flow. If the in vitro results here are compared with the whole HLM/patient system [4] the following result is found: the participation of the ECC with on average 2.5 HITS/min from the total emergence of microbubbles (11.6 HITS/min [4]) is in the range around 20%. The applied surgical techniques, the medication application and other factors are therefore of decisive significance for neurological success/outcome.

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INTRACARDIAC LEFT VENTRICULAR ASSIST IN MINIMALLY INVASIVE HEART OPERATIONS

Background: Less invasive surgical procedures without the aid of extracorporeal circulation are becoming more significant. The basic prerequisite for a good long-term result is, however, the complete revascularization of the affected coronary vessels. The unsatisfactory high conversion rate of bypass operations originally planned to be off-pump to conventional operations with heart-lung machine due to the inability to reach the target vessels on the rear wall of the heart during haemodynamic instability gave rise to the investigation of the efficiency of a microaxial pump (Impella elect) placed left ventricularly.

Method: In 15 of 38 prospectively randomized consecutive patients who were planned to have a coronary revascularization by beating heart, a left ventricular micropump was implanted transaortally. The heart was assisted during the operation with a flow rate of 2.5–3.9 L/min the control group contained 23 patients who could not be differentiated between in their demographic or preoperative state.

Results: Eight of 23 patients (34%) who were operated on without pump assist had to be converted to the conventional procedure with heart-lung machine. Only one patient (6%) from the left ventricular assist group had to be further operated conventionally because of intramyocardial lying LAD ($p < 0.05$). The investigated laboratory parameters, in particular CK, CK-MB, and clotting parameters, showed no significant differences. The pump-assisted patients tended to demonstrate higher blood loss.

Discussion: The use of a left ventricular microaxial pump seems to enable complete revascularization in almost all patients by comparable results.

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CARDIOVENTION COR-X—A NOVEL OXYGENATION-SYSTEM FOR EXTRACORPOREAL SUPPORT IN MINIMALLY INVASIVE CARDIAC SURGERY

Background: A significant trend toward minimizing trauma related to cardiac surgery is aimed at modifications or elimination of cardiopulmonary bypass (CPB) altogether. Minimizing neurocognitive outcomes is of keen interest because of the high human cost associated with stroke and neurocognitive deficits. Recently, efforts to completely eliminate CPB have resulted in potential risks to cardiovascular procedures that may offset any real or perceived benefits. Specifically, neurological benefits of off-pump bypass have not yet been clearly demonstrated relative to the risk of a more technically challenging operation. Therefore, new technology designed to provide incremental improvements of the gold standard of CPB are rapidly developing, offering such features as reduced priming volume and elimination of cardiectomy reservoirs. The CardioVention System has a unique feature (AirVac™), which actively removes air and microbubbles from the system.

Method: The CORx-system was used from November 2001 to May 2002 in 37 coronary artery revascularisations. Thirteen cases were performed in beating heart technology, in 24 cases, Calafiore Blood cardioplegia was used. The CORx-system does not contain any heat exchanger. During the open-chest procedure, the patient core temperature drops to $34.3 \pm 0.5^\circ\text{C}$. That prompted us to use an additional cardioplegia heat exchanger (CSC 14, Sorin-Italy). The heat exchanger bypassed the CORx from arterial outlet to venous inlet. Cardioplegia cooling and systemic rewarming became possible.

Results: The set up and usage of the new system is very easy and uncomplicated. Because of the very low priming volume (all components, inclusive arterial line and pre-bypass filter, heat exchanger 750 cc) was the hematocrit at the heart-lung-machine $34.6 \pm 4.4\%$ (compare: standard ECC $26.4 \pm 3.0\%$). The reduced hemodilution caused the mean venous saturation $78.3 \pm 4.5\%$ (compare: standard ECC $75.9 \pm 0.4\%$). Without any heat exchanger, it was difficult to impossible to rewarm the patients. With an integrated heat exchanger patients could rewarmed to $36.3 \pm 0.2^\circ\text{C}$. The heat exchanger flow was not higher than 1.5 lpm. Rewarming time was between 10 to 15 min.

Conclusion: The CardioVention CORx is a very safe and easy to use minimized heart-lung machine system. The very low priming volume reduces hemodilution and increases the oxygen carrying capacity during cardiopulmonary bypass. This reduces blood damage and air emboli and may offer improvement in neurologic outcomes in cardiovascular surgical procedures.

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MINIMALLY INVASIVE CORONARY REVASCULARIZATION WHEN USING DIFFERENT STABILIZERS AND ST. JUDE CONNECTOR

Background: Coronary revascularizations without extracorporeal circulation (ECC) are becoming more common in the therapeutic spectrum. This 'off-pump' surgery can avoid ECC-associated negative effects and be of advantage, particularly to critically ill and polypathic patients. With the introduction of minimally invasive operation methods, the technical feasibility of the operations have come to the fore. With increasing experience and regular perfectioning of the stabilizing system, it is now possible to carry out complete revascularizations. Also in addition, the use of arterial grafts is also possible in 'off-pump' operations without restrictions.

Method: From 6/1998 we operated on 241 patients (182 m/59 f) with minimally invasive techniques without ECC. To begin with the revascularization of single vessel diseases with connection to RIVA and RD initially took place, then later patients with 2-vessel-KHK (additional revascularization of RCA) were treated. The Octopus/Octopus II as well as the Mawitec System served as stabilizer systems. With the introduction of the XPOSE Access Device (Guidant) it was possible to undertake complete revascularizations up to fivefold bypass supply. The complete arterial revascularization was achieved in 137 patients, which represents 56.8%. Since 12/2000 the St. Jude device (Symmetry™) was used in 19 patients for the creation of proximal vein anastomoses to perfect the minimally invasive OP methods concept (aortic connector).

Results: 396 grafts were used for 396 distal anastomoses. All patients received at least one arterial graft (left, right A. mammaria, A. radialis). The perioperative 30-day mortality was 0.83% (n = 2). In five cases, there had to be an intraoperative conversion to ECC. All patients in whom the proximal vein anastomosis was created by the Symmetry™ system, underwent an elective CT and angiography control after 6 months. The examination showed all arteria mammaria grafts were open. Four RD grafts (from 14 [28.6%]) and one RCA bypass (from 5 [20%]) were closed.

Table 1.

Applied Stabilizing Systems In 241 Patients		Revascularisations Carried Out		Particulars	
OCTOPUS I	n = 61	1 Vessel supply	n = 120	Use in reoperation	n = 3
OCTOPUS II	n = 64	2 Vessel supply	n = 91	Combination with Carotis Tea	n = 3
MAWITEC	n = 101	3 Vessel supply	n = 26	Use in emergency operation	n = 2
XPOSE-Access-Device	n = 13	4 Vessel supply	n = 3	p.o. wound infection	n = 4
Without device	n = 2	5 Vessel supply	n = 1	Re-op due to bleeding	n = 5
St. Jude device	n = 19			Re-op due to LCO	n = 2
				Postoperative IABP	n = 2
				Postoperative assist device	n = 1

Conclusion: Coronary surgical off-pump revascularization is an accepted and increasingly used minimally invasive operation procedure, which with increasing perfection of the stabilizing systems as well as the introduction of new devices for the creation of proximal and maybe distal anastomoses are taking ever increasing place in daily heart surgery. This should make it possible to provide, especially those critically ill patients, with 'their' operation.

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INDICATIONS AND LIMITATIONS OF MINIMALLY INVASIVE CORONARY REVASCULARIZATION—WHO SHOULD, WHO COULD, AND WHO SHOULD NOT BE OPERATED OFF PUMP?

Background: The number of minimally invasive operations (off-pump revascularization) is increasing constantly both nationally and internationally. The avoidance of the heart-lung machine as well as the associated side effects of perfusion in the sense of protection of cardiac and extracardial organ functions are unanimously proved advantages of this procedure. The majority of German Heart Centers are currently carrying out between 6% and 12% of all coronary surgical revascularizations as off-pump operations. In particular, all cardiac flow areas can be reached through the introduction of new exposure aids (X-pose, starfish, etc.). Now that technical (exposure) problems no longer play a major role, the question is: *Are there patients who are not suited for an off-pump revascularisation?*

Method: From June 1998 to now around 300 patients were operated on in our clinic using different minimally invasive techniques. After the accessibility of the "target vessel" was determined, the existing co-morbidity is the most important factor in the choice of procedure. With increasing experience, selected clinical situations as well as morphological state have proved to be inadvisable for an off-pump operation. Taking this into consideration in only five cases (<2%) revascularization was possible but only with later use of the heart-lung machine.

Results:

Table 1.

OP length (min)	151 (85–260)	Grafts/"Target Vessel"	
Troponin (ng/mL)	0.146 (<0.01–0.82)	LIMA	244 (57.8%)
CK (μ kat/L)	12.3 (1.99–79.9)	RIMA	13 (3.1%)
CKMB (μ kat/L)	0.47 (0.01–1.56)	A. radialis	36 (8.5%)
Re-op due to bleeding (N)	5 (2.2%)	Veins	129 (30.6%)
Low cardiac output (N)	3 (1.3%)	1 Vessel disease	68.2%
Blood products (units/pt)	0.79 ($\pm$ 0.5)	2 Vessel disease	21.0%
Wound infections (N)	4 (1.7%)	3 Vessel disease	10.8%

Conclusion: The perioperative mortality was 0.3% (one patient); all other patients left the clinic for rehabilitation. The careful selection of the patients and the critical pre- and intraoperative evaluation of the limitations of the various procedures as well as the current situation allow excellent results in off-pump revascularization.

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REDUCTION OF THE REFLUDAN DOSAGE IN HIT PATIENTS THROUGH THE MECC SYSTEM

Background: In patients with heparin-induced type II thrombocytopenia (HIT) the recombinant hirudin with the trade name Refludan® is used as a replacement for heparin. The break down of the anticoagulant with a half-life period of 1–4 hours takes place solely renally because there is no antagonist available. During the Refludan effect duration, the risk of bleeding increases. That is the reason for reducing the amount of applied Refludan.

Method: For this reason, a minimal extracorporeal circuit (MECC) was utilized in four patients who underwent an ACB operation (Figure 1). The MECC set utilized in the HIT patients is uncoated.

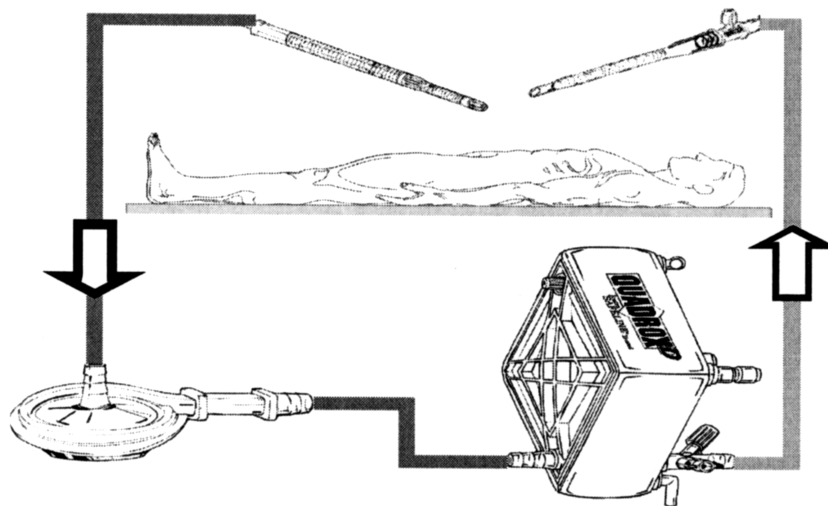


Figure 1. MECC system with standard cannulization.

Results: The MECC system enables halving the intravenous bolus dosage, the priming dosage and the continual perfusor dosage of Refludan in contrast to the standard heart-lung machine.

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DEVELOPMENT OF AN ENDOSCOPIC STABILIZER FOR ROBOT-SUPPORTED HEART OPERATIONS

Background: Since the beginning of 2000, total endoscopic bypass operations (TECAB) are being carried out in increasing numbers with the aid of telemanipulator systems. The reduction of surgical access to the heart (keyhole surgery) and the thereby reduced space to work in, in comparison to conventional surgery, means that the instruments and materials that are currently used can only be utilized conditionally for minimally invasive use.

The object of this article is the presentation of the development, construction, and fabrication of the prototype ES2.0—TUDä—an endoscopic insertable stabilizer. This instrument allows the siting of anastomoses on the beating heart by ensuring the necessary immobilization of the concerned area of the heart. How the difficult kinematics of endoscopic surgery is circumvented and a free maneuverability of the stabilizer internally achieved, are described. The formation of the stabilizer foot accompanied theoretical investigations on the interaction between the stabilizer foot and heart tissue, whereby a design could be found that minimized tissue trauma. The handling of the instrument has been organized in such a way that a definite, direct, and intuitive manipulation can occur. The instrument design and the used materials (surgical steel) allow up to 100 application cycles.

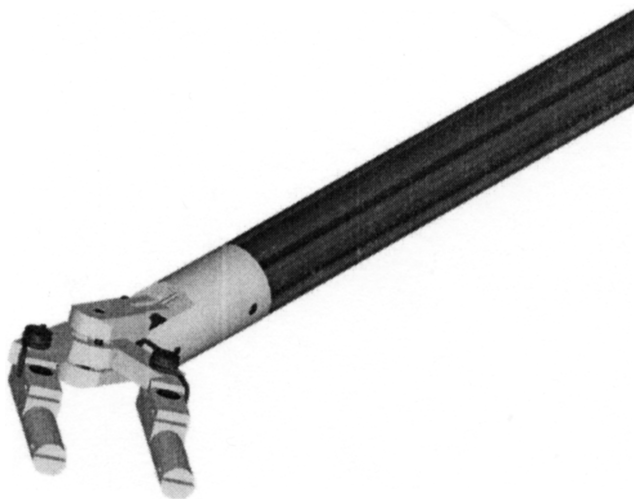


Figure 1. Design of the stabilizer foot.

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INTRAOPERATIVE RADIO FREQUENCY ABLATION FOR TREATING IMPENDING ATRIAL FIBRILLATION IN PATIENTS WITH VALVE AND/OR CORONARY SURGERY: SHORT TERM RESULTS

Background: Since the end of December 1999 patients with valve and/or coronary surgery in selected cases with secondary known atrial fibrillations with the use of radio frequency ablation have been treated in our clinic. Until December 2001, we used this method on 43 patients (22 women, 21 men) with an average age of 67 ± 6.86 . In six patients, the atrial fibrillation had occurred intermittently preoperatively, in the other patients chronically.

Method: The operations took place after median sternotomy during cardioplegic cardiac arrest (blood cardioplegia after calafiore); in 15 cases isolated in the mitral valve, in 10 cases in the coronary arteries, in 6 cases combined in the mitral and aortal valve, in 6 cases in the mitral valve and coronary arteries as well as 6 cases isolated in aortal valve. Finally, the ablation probe (10-mm rod electrode from the company: Sulzer-Osypka GmbH, Grenzach-Wyhlen, Germany) was brought forward via the left atrial entry and warmed to a temperature of $60-65^\circ$ for 30 seconds at a time by using a 500 kHz generator (HAT 200S, Sulzer-Osypka).

Results: In 31 patients a sinus rhythm could be determined immediately operatively. In one case atrial fibrillation continued, in 11 cases the atria stood. If in further postoperative course of events, atrial fibrillation occurred, the patients were cardioverted and/or set onto Solatol/Amiodaron. Thirty of the patients (70%) could to be discharged from our institute with a stable sinus rhythm, in 11 patients (26%), the atrial fibrillation continued. In one patient, atrial fibrillation continued to occur intermittently. One patient died at the end of the operation from protracted cardiogenic shock. In echo and cardiographically tests carried out at the earliest 3 months postoperatively 19 patients (67.9%) showed an intermittent sinus rhythm. Of these three patients, one of whom was being treated with Flecainid, three were treated with Cordarex and 11 with Solatex. Of the five patients who underwent a sole bypass operation, only one (20%) converted permanently into a sinus rhythm. Among the 23 patients with purely valve specifically combination operations 18 (78.3%) showed a sinus rhythm at the time of control.

Discussion: In summary, it can be said that our results are comparable with those of previous publications and, therefore, intraoperative radio frequency ablation can be considered as an uncomplicated option for treating atrial fibrillation in patients with simultaneous aorta or mitral valve surgery.

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EFFECTS OF CARDIOPULMONARY BYPASS ON LEFT VENTRICULAR FUNCTION USING THE CONDUCTANCE CATHETER TECHNIQUE

Background: Postoperative cardiac depression is attributed to ischemia and the effects of cardiopulmonary bypass (CPB). To evaluate the effect of CPB alone on postoperative left ventricular (LV) dysfunction, we used a conductance catheter to determine the LV performance by pressure–volume relation before and after CPB.

Method: Twenty-two 3-week-old piglets underwent sternotomy and normothermic CPB for one hour. The conductance catheter was placed in the LV cavity. End-systolic pressure–volume relationships (ESPVR), left ventricular end-diastolic pressure (LVEDP) and systemic vascular resistance (SVR) were measured in steady-state conditions before and 15 min after weaning from CPB in group A (n = 10). Group B (n = 10) served as control group without CPB.

Results: Indicating an impaired LV function the slope of ESPVR (mmHg/mL) was significantly lower in group A after weaning from CPB than in group B (1.85 ± 0.58 vs. 2.07 ± 0.7 ; $p < .009$). In group A, peak dP/dt (mmHg/sec/kg) decreased markedly (67.7 ± 15.9 vs. 81.9 ± 15.2 ; $p < .0001$), while LVEDP (mmHg) was significantly increased (11.6 ± 2.5 vs. 7.28 ± 1.3 ; $p < .001$). In addition, SVR (dyn.sec.cm-5/kg) was significantly lower in groups B (47.6 ± 18.9 vs. 78.3 ± 45.2 ; $p < .04$). We found no significant changes between groups before initiating CPB and in the control group.

Discussion: The use of CPB leads to significant depression of LV function even without ischemic arrest in the early post-CPB period. This may be caused by a reduction of coronary perfusion during CPB or the whole body inflammatory response.

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MORPHOLOGICAL CHANGES IN HYPERTROPHY RV DUE TO TETRALOGY OF FALLOT

Background: The aim of the study was to analyze the influence of hypertrophy and hyperplasia on thickness increase of RV wall assessed by morphometric methods in tetralogy of Fallot.

Methods: Investigated group consisted of 53 patients, aged 11–144 months (mean 38 months). Specimens taken from right ventricle outlet tract in TOF patients were analyzed. The control group consisted of 10 specimens of normal hearts of infants aged 5–118 months (49.5 months) taken during autopsy. The same morphometric methods were used to analyze control group.

Results: The following morphometric parameters were compared between studied and control group: diameter of myocytes: $15.6 \pm 2.3 \mu\text{m}$ vs. $5.2 \pm 0.6 \mu\text{m}$ ($p < .001$); mean diameter of nucleus $3.8 \pm 0.6 \mu\text{m}$ vs. $3.2 \pm 0.4 \mu\text{m}$ ($p < .001$), number of nuclei/ mm^2 of the specimen: 1576 ± 611 vs. 3325 ± 545 ($p < .001$), extent of fibrosis: $7.7 \pm 3.1 \%$ vs. $4.18 \pm 0.9 \%$ ($p < .001$) respectively.

Discussion: The enlargement of the myocardium in TOF is caused by hypertrophy of myocytes but influence of the myocytes hyperplasia on myocardium thickness remains to be established.

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REDUCED CYTOKINE SYNTHESIS CAPABILITY IN WHOLE BLOOD: ROLE OF CPB AND ANTI-INFLAMMATORY MEDIATORS

Key point: Operations with the aid of extracorporeal circulation (CPB) lead not only to the release of pro (tumour necrosis factor-TNF alpha interleukin (IL)-6 and IL-8 but also anti-inflammatory cytokine (IL-10, transforming growth factor- β). This release of cytokine is, on the one hand, connected with the development of the generalized inflammatory reaction (SIRS) after CPB. On the other hand, it leads to destruction of the cellular and humoral immune response. For a better description of the regulation of immune cell functions after heart surgery operations and the role of CPB in this connection, we investigated endotoxin (ET) induced cytokine synthesis in the whole blood of patients and in an *isolated* CPB system.

Materials and Methods: We extracted whole blood and serum probes before, during, and after CPB in 15 patients, who were operated under the conditions of a normothermic CPB. The full blood cultures were stimulated for 4 hours with ET (100 ng/ml). Finally, the concentrations of TNF alpha IL-6 and IL-8 in the culture rest and serum were determined using ELISA. We conducted a supplementary investigation on the cytokine synthesis capability of the test person whole blood that had circulated for over 120 min in an isolated CPB system.

Results: The *ex vivo* cytokine synthesis capability in the whole blood of all patients was after CPB significantly suppressed (TNF alpha: 11%; IL-6: 29%; IL-8: 48% of the preoperative starting values, all were $p < .05$). In the isolated CPB model, a time-dependent reduction of the cytokine formation with a maximum after 90 min was found (TNF alpha :33%; IL-6: 15%, $p < .05$). Patients' serum extracted after CPB was able to inhibit the ET induced TNF alpha synthesis in heterologous whole blood from healthy test persons. In the isolated CPB model, this cytokine inhibitory activity was not found.

Conclusion: (1) the ET-induced cytokine synthesis capability of whole blood is significantly suppressed after CPB; (2) Blood contact with foreign surfaces and/or shear stress also leads to suppression, like (3) cytokine inhibitory mediators, which circulate *in vivo* in the serum after CPB; (4) Immune cell functions, such as, e.g., cytokine synthesis capability, are destroyed after CPB and increase the susceptibility of patients to infections.[Financial assistance from the DFG (Schm 74/13-2) and IFORES University Essen (J.B.)].

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RECOVERY OF IMMUNE RESPONSE AFTER EXTRACORPOREAL CIRCULATION WITH HAEMATOPOIETIC GROWTH FACTORS IN VITRO

Key point: Large operations as well as trauma or septic patterns lead to a dysregulation of the cellular and humoral immune response. The current immune status can be characterized through the function parameters of the immune system, such as the cytosynthesis capability of whole blood cultures *ex vivo* or by the HLA-DR-expression on monocytes. Therefore, in this study, we have investigated both these parameters in heart surgery patients in the perioperative process. The effect of the hematopoietic growth factor granulocyte-macrophage-stimulating-factor (GM-CSF) was observed on the same model for comparison

Material and Methods: We extracted whole blood probes before, during and after CPB in patients who were operated on under the conditions of the normothermic CPB. The whole blood cultures were pre-incubated for 20 hours without (a control) and with GM-CSF (1–100ng/mL), finally, stimulated for 4 hours with endotoxin (100 ng/mL) and the TNF alpha concentration in the culture rest measured using ELISA. The HLA-DR-expression on the monocytes was determined flow cytometrically.

Results: After CPB the TNF alpha production in endotoxin stimulated whole blood cultures was significantly reduced in comparison to cultures taken preoperatively. Through 20 hours preincubation with 1–10 ng/mL GM-CSF the TNF alpha synthesis capability could be restored to around 75%. With 100 ng/mL GM-CSF the reduction was completely removed. The expression of HLA-DR molecules on monocytes was significantly reduced after CPB in comparison to preoperative start values and fell again on the second postoperative day (143.44 ± 2.04 MFI preoperatively vs. 124.67 ± 3.94 MFI after CPB and 101.27 ± 2.23 MFI 2. pop day, $p < 0.05$). The HLA-DR expression on monocytes was raised into a maximal area through preincubation with GM-CSF and no longer differed to one another to the points of time before the operation and after the CPB.

Conclusion: Heart surgery operations with CPB lead to suppression of the immune response. This shows itself not only in reduced cytokine synthesis capability *ex vivo* but also in a reduced HLA-DR expression on monocytes. Hematopoietic growth factors, such as GM-CSF, can remove this phenomenon through their immune stimulating effect and thereby represent a potential therapy for states of immune paralysis. [Financial assistance from the DFG (Schm 74/13-2) and IFORES University Essen (J.B.)].

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HOW HARMFUL IS MODERN EXTRACORPOREAL CIRCULATION? CAN THE STANDARD BE REACHED BY OPERATIONS WITHOUT THE HEART-LUNG-MACHINE?

Background: Many work groups have tried to reach an improved tolerance to ECC through modifications to the extracorporeal circulatory system (ECC). The goal is to bring the reaction of the body down to the level of operations without ECC. Among other things surface modification of the ECC as well as discarding of suction blood have been promulgated.

Method: Forty patients with isolated coronary revascularization (EF >30%, normal kidney function, no significant associated diseases) were divided into four groups.

- Group I no ECC MIDCAB
- Group II cECCSBS "Phisio"® coated ECC with suction blood separation (SBS)
- Group III uECC uncoated ECC without suction blood separation
- Group IV uECCSBS uncoated ECC with suction blood separation

The compartmentation of the suction blood took place with the "Avant" Reservoir D970® (Stöckert Instrumente GmbH, Munich). The tube systems and the cannula used were identical, and the coating of the ECC took place in group II from "Tip to Tip". At five times of measurement (before ECC, 15 mins ECC, 5 min aorta open, after ECC, 1st post.op day) different parameters of mechanical trauma, of the activation of clotting specifically of fibrinolyse, of the thrombocyte function, of the influence on the corpuscular components as well as immunological parameters were investigated and evaluated. In addition, an evaluation of the perfusion technical parameters took place.

Results: The data from the cardio engineering databank showed no significant differences between the three ECC groups with regard to bypass time, flow rate, SBS volume as well as EC addition. In the two SBS groups significantly more colloidal, i.e., crystalloid solutions were administered during ECC. At the end of ECC the hemoglobin and hematocrit concentrations in the SBS groups, however, were not statistically significantly lower than in the conventional group II. The fHb directly after ECC was in group II statistically not significantly raised in comparison to the MIDCAB group, the plasmin antiplasmin complex (PAP), thrombin antithrombin complex (TAT), and prothrombin fragment 1+2 and S100 acted similarly. The hemoglobin and hematocrit concentrations were lower in all ECC groups than in the MIDCAB group I; whereas, the addition of erythrocytes and fresh plasma in groups I and II showed no significant differences.

Discussion: The suction blood separation with aid of the D970® Reservoir in coronary revascularizations is a simple and safe procedure. Through the use of a reservoir, the highest possible safety for the patient is achieved, even in unexpected situations. The low inflammation level of operations without using heart-lung machine can almost be reached in coronary revascularizations through the combination of suction blood separation with "PHISIO" coated ECC systems.

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CORRELATION OF INTRAOPERATIVE VALUES WITH POSTOPERATIVE RESULTS IN 130 PATIENTS WITH FOUR DIFFERENT MEMBRANE OXYGENATORS

Background: Optimized in-vitro data of oxygenators (MO) should also correlate with an improved intraoperative performance and optimize the postoperative quality of results.

Method: 130 patients were investigated in four groups: I Maxima, n = 10; II Affinity, n = 40 (both Medtronic Inc.); III Vision, n = 40 (Gish Biomedical); and IV Capiox RX-25, n = 40 (Terumo). During perfusion at four fixed time points (5/30/60 min and achievement of normothermia) the following parameters were determined: pressure drop, O₂ and CO₂ transfer, gas flow, shunt fraction, FiO₂, O₂ diffusion capacity, max. O₂ transfer per m² membrane surface (MOF), art. $\dot{V}_{O_2}$, $\dot{V}_{CO_2}$ and saturation as well as venous O₂, CO₂ and saturation. Laboratory data (hematocrit, hemoglobin, leukocytes, thrombocytes, creatinine, urea) and data of the clinical procedure (diuretics and foreign blood use, drainage help, extubation time, intensive medical therapy duration, occurrence of symptomatic transitory psychotic syndromes) were contrasted to the parameters above.

Results: For the evaluation the results of groups I–III were summarized and compared to group IV: the MO of groups I–III differentiated marginally during perfusion (Vision showed a 5–8% low shunt, a low O₂ gradient and CO₂ transfer and an around 15–20 mmHg higher pressure gradient). In group IV, the following differences in comparison to groups I–III occurred (after 60 min perfusion): pressure gradient 69.5 mmHg (25–125) vs. 82 mmHg (50–125); O₂ gradient 168.5 mmHg (44–283) vs. 121.5 (28–283); O₂ transfer 101.1 mL/min (17.7–225.2) vs. 77 mL/min (25–147); CO₂ transfer 76 mL/min (40–202.4) vs. 54 mL/min (32–88); shunt fraction 21.4% (6.3–34.7) vs. 19.2% (6.3–42.7); max O₂ transfer/m² MOF 40.5 mL/min/m² (7.1–90.1) vs. 31.1 mL/min/m² (10.1–58.8). The results postoperatively were as follows:

Table 1.

	Group I	Group II	Group III	Group IV
Symptomatic transitory psychotic syndromes (N):	1	2	4	2
Mean i.v. diurectic requirement (mg):	120	100	130	100
Mean creatinine (mg/dL):	1 (0.6–2)	1 (0.5–2.1)	1.1 (0.6–2.9)	1 (0.7–1.7)
Mean foreign blood use (EK; units):	3.1	2.9	3.3	1.3
Artificial respiration time >24 hours. (N):	2	6	8	3
Total mean drainage loss (mL):	980 (350–900)	949 (300–2400)	1156 (250–3100)	968 (165–3590)

Discussion: In comparison to in-vitro data, for all four MO the intraoperative performance data of the oxygenator Terumo Capiox RX-25 could be improved with respect to gas transfer in similar shunt ratios and gradients. Similarly reduced oxygenator associated morbidity was found clinically.

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LEUCOCYTE FILTRATION FAILS TO PREVENT NEUTROPHIL-MEDIATED PATHOGENICITY DURING CARDIAC SURGERY IN HIGH-RISK PATIENTS

Background: Leukocyte filtration (LF) is used to reduce neutrophil-mediated pathogenicity in cardiac surgery with cardiopulmonary bypass (CPB). However, the benefit of LF in high-risk patients is unclear. Therefore, we studied the efficacy of LF on the clinical outcome in high-risk patients. In addition, surrogate markers for myocardial damage, inflammatory response, and cerebral disorder were evaluated.

Method: In a prospective randomised trial with 50 high-risk patients (parsonnet score over 20 pts.) the cerebral injury markers neuron specific enolase (NSE) and S100B were quantified by immunoluminometry. The inflammatory response markers myeloperoxidase (MPO), polymorphnuclear elastase (PMNE) and procalcitonin were measured by ELISA. Leukocyte counts were determined by hemocytometry. Troponin T, CK/CK-MB were quantified (ELISA) to assess myocardial damage. Patients were assigned to two groups: (1) CPB without LF; (2) heparinized CPB circuits with arterial LF (Leukoguard LG6; PALL). Blood samples were obtained (A. radialis): (1) before anaesthesia; (2) before CPB; (3) 1 min after x-clamp release; (4) end of operation; (5) 1h and F) 24 h after operation.

Results: Clinical data (mechanical ventilation, postoperative bleeding, ICU and hospital stay, and neurological outcome) did not differ between groups. No significant intergroup differences for NSE, S100B, MPO, leukocyte counts, procalcitonin, troponin T, CK/CK-MB was found. In contrast, at time points C-E significantly higher PMNE values were detected in the LF group (Table 1). However, functional PMNE activity (succinylated elastin assay) did not differ.

Table 1. PMNE (ng/mL); Mean $\pm$ SD; A-F: Time Points.

	A	B	C	D	E	F
Control (N = 25)	35.53 $\pm$ 5.1	28.14 $\pm$ 2.4	411.41 $\pm$ 47.98	409.1 $\pm$ 54.01	515.19 $\pm$ 36.31	87.67 $\pm$ 13.11
LF (N = 25)	36.2 $\pm$ 3.91	34.9 $\pm$ 3.16	740.13 $\pm$ 79.04	676.14 $\pm$ 58.97	594.00 $\pm$ 79.01	139.88 $\pm$ 30.26
P	0.4095	0.1732	0.0023	0.0017	0.0111	0.3681

Conclusion: In high-risk patients, no evidence for clinical benefits of LF was found.

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PHOSPHORYLCHOLINE COATING OFFERS NATURAL PLATELET PRESERVATION DURING CARDIOPULMONARY BYPASS

Background: Return of blood activated by tissue factor is the main culprit for triggering the coagulation cascade. When this activated blood is diverted from the cardiopulmonary bypass (CPB), it becomes possible to evaluate the effect of surface treatment on platelet and complement activation.

Method: Twenty adult patients undergoing elective coronary artery bypass grafting (CABG) were randomly assigned either to a control group (n = 10) or to a group in which the CPB was completely coated with phosphorylcholine (n = 10). Plasma concentrations of platelet factor 4 (PF4), beta-thromboglobulin (BTG), C3, C3d, C4, TCC, thrombin generation, haptoglobin, and free hemoglobin as well as blood loss were measured.

Results: No significant differences between the two groups were found for hemolysis and thrombin generation. The mean total release of PF4 and BTG during CPB was 9338 ± 17303 IU/mL/CPB and 3790 ± 4104 IU/mL/CPB in the coated group versus 22192 ± 13931 IU/mL/CPB ($p = .011$) and 8040 ± 3986 IU/mL/CPB ($p = .005$) in the control group. Blood loss was 30% less in the coated group as compared to the control group.

Discussion: Phosphorylcholine coating seems to have a favorable effect on blood platelets, which is most obvious after studying the changes during cardiopulmonary bypass. Clinically, this effect resulted in a 30% reduction in blood loss.

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SURFACE MODIFIED (SMARxT) EXTRACORPOREAL CIRCULATION: AN IMPROVEMENT FOR NEUROLOGICAL OUTCOME?

Background: Despite the ever-increasing number of heart surgery operations without heart-lung machines, an overwhelming proportion of all operations continues, however, to be possible with the use of ECC. An optimization of the biocompatibility, therefore, also presents a focal point for research in the future. Neurological complications continue to take a leading position in the postoperative course of events. The aim of our work was to find possible proof of an improved neurological outcome after operations with heart-lung-machine with the use of the SMARxT modified systems.

Method: 50 patients were put into each arm of the prospective randomized study. One group was treated with SMARxT systems, the other groups with conventional PVC systems without any coating. The aspiration management was optimized in both systems through a closed system without coronary suction, modified vent, cell-saver and without retransfusion of pleural blood. Clinical markers (blood loss, stay in hospital, artificial respiration duration, ECC times) and blood analyses of the daily routine (Hb, creatinin, Ck, Ck-MB, C-rP) were documented pre-, intra-, and postoperatively. We also carried out a battery of neurological tests (Beck's Depression Inventory, Benton Test, D₂ Test, Trailmaking Test) not only preoperatively but also on the third and sixth postoperative days.

Results: No clinical or blood chemistry markers showed significant group differences. The neurological tests showed a bathtub-shaped characteristic in their results. The preoperative achievements could be reached again on the sixth postoperative day. Differences relating to both of the study groups could not be verified. It should be noted, however, that only 20% of all patients were clinically in a state to undergo a complex battery of tests on the third postoperative day.

Discussion: SMARxT systems can be employed without difficulty in the daily clinical routine. The verification of significant group differences was not achieved. Possible reasons for this are the group sizes (50:50) at an expected incidence rate of 2% for serious neurological disturbances but also to measure the complexity of psychological changes with a choice of four established procedures.

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EXPERIENCES WITH THE BILATERAL EXTRACORPOREAL CIRCULATION ACCORDING TO DREW WITHOUT USE OF AN EXTERNAL OXYGENATOR IN TWENTY-FOUR CORONARY BYPASS OPERATIONS

Background: In the conventional extracorporeal circulation (ECC) in the sense of a heart-lung machine, the lungs are rarely perfused via the pulmonary arteries. Some rest perfusion of the lungs via the bronchial arteries exists whose venous blood collects in the left atrium and from there is drained via an aortal or ventricular vent. The Drew method of the bilateral extracorporeal circulation functions without external oxygenators. The patient's lungs are perfused and ventilated during the whole operation and oxygenate the patient's circulating blood. We will describe the experiences in 24 patients who underwent coronary bypass operations and were perfused according to the Drew method.

Method: In addition to the right atrium and the aorta ascendens, the left atrium and the pulmonary artery are fitted with cannula. In our collective two patients to begin with were fitted with cannula via the left atrial auricle; then two patients via the atrial roof and the last 20 patients, with 32 F or 26 F wire strengthened angled cannula (Fa. Stöckert, Munich) via the upper right lung vein. For the cannularization of the pulmonary artery 20/22 F cannula (wire strengthened) were used. For the strain relief of the heart first the right-hand circuit was started up, thereafter the lung vein was cannularized and then, finally, the left-hand circuit started up.

Results: The mean priming volume was 2218 ± 77 mL. Through pharmacological increase of the peripheral resistance at the start of bypass, the last priming volumes were around 1800 mL, whereas to start with over 3000 mL were needed. The patient was respirated at the beginning of the OP with a FiO_2 of $54 \pm 4\%$ and at the end with $67 \pm 4\%$. The corresponding oxygen particle pressures thereby were 236 ± 23 and 233 ± 14 mmHg. The number of the peripheral anastomoses was 3.0 ± 0.2 , the clamp time 64 ± 4 min, the machine time was 109 ± 5 min. The balance of the introduced volume at the end of the operation was $+2292 \pm 106$ mL. The flow rates of the right-hand circuits were 10-20% less than the flow rates of the left-hand circuit as a result of differing pulmonary resistances and volume displacements. There were no deaths. In one patient, a conversion to conventional HLM was undertaken because the removal of the cannula in the left atrial auricle led to bleeding from the auricle where the IMA anastomose came out during its treatment.

Summary: For cardioengineering operations with bilateral extracorporeal circulation mean prolonged set-up times and more elaborate bypass conduction. From a surgical point of view, the Drew technique allows a coronary bypass operation to be carried out in uncomplicated patients, under acceptance of a minimally increased operative time through the placement and removal of two additional cannula. The increased priming volumes, caused by use of two reservoirs, can be considerably reduced, in cooperation with anesthetics, through the lifting of peripheral resistance at the beginning of the operation. It is currently being investigated whether the Drew technique leads to a reduction of mortality and morbidity in patients with seriously limited lung function.

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TRANSFER OF VOLATILE ANAESTHETIC AGENTS IN MICROPOROUS-CAPILLARY AND DIFFUSION MEMBRANE OXYGENATORS

Background: Guaranteeing a sufficient narcosis depth during a running ECC is principally possible in two ways: through complete intravenous application of the required anesthetic or through the administration of an inhalation anesthetic via the membrane oxygenator (MO). This implies the administered gasses can also penetrate through the membranes. Today MOs with a microporous capillary membrane (CMO) made of polypropylene are standard. Newly offered diffusion MOs have a so-called solid (impervious) diffusion membrane made of poly-(4-methyl-1-penten). The following study investigates just how permeable this is for anesthetic gasses.

Method: In 90 ACB operations, different MOs were employed. The narcosis was fed in with fentanyl (5 µg/kg), etomidate, and pancuronium (100 µg/kg), and perpetuated with a continual propofol infusion (3–5 mg/kg/h) supplemented through bolus additions of fentanyl (up to 20 µg/kg) and pancuronium (50 µg/kg) as needed. In a period of 30min during the aortal unclamping time, the anesthetic gas transfer of the isofluran and desfluran at constant inspiratory concentrations of 1.0 and 2.0 vol%, respectively, was measured via the MO [wash in (15 min) and wash out (15 min)]:

Table 1. Investigated Oxygenators.

Model	Membrane	Fibers	Coating	Fiber Manufacturer
QUADROX ^D	Solid	Poly-(4-methyl-1-penten)	None	Membrana
QUADROX ^D BE	Solid	Poly-(4-methyl-1-penten)	Bioline	Membrana
QUADROX Safeline	Microporous	Polypropylene	Safeline	Membrana
HILITE [®] 7000 LT	Solid	Poly-(4-methyl-1-penten)	Rheoparin	Membrana
HILITE [®] 7000	Microporous	Polypropylene	None	Membrana
Capiox RX25	Microporous	Polypropylene	Xcoating	Terumo
Affinity [®] NT	Microporous	Polypropylene	Trillium	Celanese

Results: Anesthetic gas can penetrate the MO with a separation layer made of microporous polypropylene capillary into the patient's blood. If the separation layer is made of a solid membrane (Poly-(4-methyl-1-penten) no transfer worth mentioning takes place either of isofluran or desflurane.

Table 2. The Maximal Expiratory Concentration of the Anesthetic Gasses, for Example, on an MO, That is Equipped Once with a Solid Poly-(4-methyl-1-penten) and Once with a Microporous Polypropylene capillary.

Model	Membrane	Inspir. Conc.	Expiratory Concentration	
			After 5 min "Wash in"	After 15 min "Wash in"
HILITE 7000 LT	Microporous	1.0 Vol%	0.96 ± 0.02 Vol%	0.97 ± 0.02 Vol%
HILITE	Solid	1.0 Vol%	0.51 ± 0.05 Vol%	0.60 ± 0.10 Vol%

Summary: Should volatile anaesthetic be applied via the MO, it should first be checked whether the used membrane is permeable to the corresponding gas. Otherwise, the depth of narcosis could be insufficient.

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INTRAOPERATIVE DIALYSIS VERSUS HEMOFILTRATION DURING HEART OPERATIONS WITH HEART-LUNG MACHINE

Background: Intraoperative management of chronically dialysis-dependent heart patients is the subject of controversial discussion. The aim of this study was to investigate the effects of intraoperative dialysis and hemofiltration on the postoperative course of events.

Method: In a retrospective study from 1995 to March 2001 we investigated 53 consecutively chronically dialysis-dependent patients who underwent a heart operation. five patients were excluded from the study. The patients were divided into two groups: In 18 patients an intraoperative hemodialysis (group 1) and in 30 patients an intraoperative hemofiltration (group 2) was carried out during ECC. Within the framework of the Heidelberg Society for multicentre data analysis (HVMD) altogether 1500 parameters of the pre-, intra-, and postoperative course of events with a follow up of 6 months were collected and evaluated using uni- and multivariate analyses.

Results: The preoperative characteristics concerning gender, age, underlying illnesses, risk factors, preoperative hemodynamics and NYHA stages were similar. Likewise, the underlying kidney illnesses of chronic dialysis were not significantly different (chron. GN: 9 vs. 6; diabetes mellitus: 2 vs. 5; nephrosclerosis 0 vs. 3; IN: 1 vs. 7; polycystic kidneys: 4 vs. 3; others: 1 vs. 4). The duration of dialysis before the operation showed a tendency towards higher values in group 1 (90 ± 73.8 vs. 58.3 ± 68.0 months) without reaching a significant level. The intraoperative variables (carried out operations, bypass time, aorta unclamping time, filtration quantity, foreign blood quantity, intraoperative catecholamine addition) were not significantly different. The intraoperative bicarbonate requirement was significantly lower in group 1 (70 ± 52 vs. 233 ± 204 ml, $p = .004$). Postoperatively there were no significant differences with regards to catecholamine addition, antirhythmic therapy, drainage losses and foreign blood supplies, intubation time, and stay in intensive care. Occasionally significantly lower urea ($p < .010$) and creatinin values ($p < .02$) were seen during the first 16 postoperative hours. The postoperative total mortality was also not different. (0/18 vs. 3/30).

Discussion: Chronic dialysis patients have a clearly increased risk of mortality (7%). Because the intraoperative dialysis procedure has no substantial influence on the postoperative course of events the extra costs and the considerably greater logistical effort for an intraoperative hemodialysis is not justified.

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PROTECTION AGAINST SPINAL CORD ISCHEMIA DURING DESCENDING THORACIC AND THORACOABDOMINAL AORTIC SURGERY

Background: Pathological conditions and corrective measures during descending thoracic and thoracoabdominal aortic surgery of the aorta involve the arteries arising from the aorta. Therefore, operative and perfusion protocols must account for the protection of the myocardium, brain, spinal cord, kidneys, as well as the avoidance of coagulopathy. In temporary ischemia, primarily time, as well as, hypoxia, proximal and distal arterial blood pressure, spinal fluid pressure, reperfusion factors, and temperature, become critical factors. Most dramatic in the interruption of spinal blood flow during the surgical intervention for descending thoracic and thoracoabdominal aortic disease is the resulting high incidence of paraparesis and paraplegia.

Method: A short review is made of the anatomy of the blood supply to the spinal cord and the various techniques that are presently used to counter ischemic spinal injury measures during descending thoracic and thoracoabdominal aortic surgery. Case studies are presented detailing the use of hypothermia, distal perfusion, hypothermic circulatory arrest, cerebrospinal fluid drainage, and selective perfusion strategies to other organs.

Results: Post-operative paraplegia for primary elective is approximately 5% and for reoperation, 5–15%; whereas, a review of the current literature reports postoperative paraplegia to be as high as 40%, depending on the aortic pathology and extent of required resection. Progressive improvement in survival rates and incidence of post-operative paraplegia related to intra-operative support techniques is observed.

Conclusion: The presence of dissection pathology in the thoracoabdominal aneurysm, poorly controlled intraoperative hemodynamics and cerebral spinal fluid pressures greatly increase the risk of spinal cord ischaemia. The incidence of injury to the spinal cord during thoracoaortic surgery is also related to the extent of required resection and the length of the thoracic aorta involved. The approach of enhancing the protection of the spinal cord during thoracoabdominal aortic surgery can lead to a further reduction in post-operative paraplegia in thoracic and thoracoabdominal aortic surgery of the aorta.

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ALTERATIONS IN THYROID HORMONE LEVEL IN INFANTS DURING AND AFTER CARDIOPULMONARY BYPASS

Background: Alterations in serum concentrations of total and free triiodothyronine, total and free thyroxine, reverse-triiodothyronine and thyroid-stimulating hormone occur in patients with nonthyroidal illnesses. These changes are caused by the trauma of the surgery, extracorporeal circulation, hypothermia, hemodilution, heparine, and probably by ultrafiltration. The mechanism of low total triiodothyronine and high reverse-triiodo-thyronine is well understood. It is caused by changes in peripheral monodeiodination. The level of 5-monodeiodinase is elevated, and the level of 5'-monodeiodinase is lowered than in normal state. That is why monodeiodination from thyroxine to triiodo-thyronine is lowered, and monodeiodination from thyroxine to reverse-triiodothyronine is elevated. The mechanism of low thyroxine and low thyroid stimulating hormone is connected with alterations in hypothalamo-pituitary-thyroid axis.

Method: Thyroid hormone status was assessed in 20 infants with congenital heart defects undergoing cardiac surgery (age range 7 days to 11 months). Blood samples were collected preoperatively, during cardiopulmonary bypass, after cardiopulmonary bypass, and also postoperatively in 1, 2, 3, and 8 day after cardiac surgery. Plasma TSH, thyroxine (T4), free thyroxine (fT4), triiodothyronine (T3), free triiodothyronine (fT3) and reverse triiodothyronine (rT3) were measured in blood samples and also in ultrafiltrate.

Results: All patients had significant ($p < .05$) reduction in serum TSH, T3, fT3, T4 and fT4, and elevation of rT3. The maximal postoperative changes of rT3 preceded changes of TSH, T4, fT4, T3, fT3. In patients with the lowest plasma T3 and fT3 concentration, the period of mechanical ventilation and intensive care treatment were significantly prolonged. Two of these patients died. FT3 concentrations in donor blood was parallel with concentration of fT3 in patients during and after cardiopulmonary bypass.

Conclusion: We conclude that nonthyroidal illness occurs in all infants after cardiopulmonary bypass. Concentrations of thyroid hormones is parallel with illness severity. Concentration of free triiodothyronine in patients after surgery depends on concentrations in donor blood.

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THE HEATER-COOLER UNIT: A CONCEIVABLE SOURCE OF INFECTION?

Background: Even normal drinking water contains pathogenic microorganisms. This may not necessarily be a danger to a healthy person but could have dangerous consequences in people with weakened immune systems.

The heater-cooler unit is connected via tubes with the heat exchange unit and/or heating pads and with them forms a contained water circulatory system that contains microorganisms and algae. Water leakage from the system cannot be prevented during connection.

Methods: Microbiological investigations; (1) direct employment and; (2) membrane filtration for legionelle determination) showed that these units are highly polluted with germs and particles. This is a potential risk for a patient, if he or she comes into contact with this water or contaminated objects; particularly if these germs get into the vascular system or airways.

Results: The high pollution with particles and algae very often leads to malfunction of the heater-cooler unit. Probes showed at 36°C >1000 colony forming units per ml (KBE/mL) and at 20°C still 55 KBE/mL. Special investigations found *Pseudomonas* and *Legionella*.

Disinfecting heater-cooler units is difficult. At present, there is no satisfactory procedure for reducing bacteria. The instruction manuals from oxygenator manufacturers rule out disinfectant. Disinfectants operating in heater-cooler units run the risk of damaging the oxygenator and also the heat exchanger unit. Until now, there are no investigations on chemical disinfectants and their effect on heat exchange unit membranes. They could lead to reduced permeability and limitation of function.

Conclusion: As an alternative to chemical and thermic disinfection we used filtration. With the filter that we used we could bring the KBE from 55/ml down to sterile conditions at 20°C and from >1000/mL KBE down to 100/mL KBE at 36°C. In addition, the pollution of algae and particles was clearly reduced.

A clear reduction in KBE reduced the danger of infection, and the exclusion of particles and algae maintains the function of the heater-cooler unit.

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PRECISE-PRIMING REDUCED EXTRACORPOREAL CIRCULATION SET-UP

Background: Priming of the extracorporeal circulation set up may cause hemodilution in cardiac surgery. Because the routine use of a centrifugal pump in every patient in our department the aim of the project was the development of a priming reduced circulation setup based on the novel non occlusive Delta-Stream™ diagonal pump (Medos-AG, Stolberg, Aachen).

Method: A new configured closed low priming system for the use in adult and pediatric cardiac surgery is presented. Total priming consists of 350 mL in adult cardiac surgery after initiation of cardiopulmonary bypass.

The use of the Delta-Stream™ diagonal pump leads to active venous drainage directly to the oxygenator and back to the aorta. Autologous blood priming is performed. A modified, volume-dependent pressure management to achieve normothermic cardiopulmonary bypass is performed. Depending on the need volume may be transfused from or to the reservoir. The usual compensatoric mechanisms such as flow regulation and management of systemic resistance are secondary.

We recommend the use of a volume-reduced myocardial protection (e.g., blood cardioplegia according to Calafiore). The regulation of preload by the console of the Delta-Stream™ diagonal pump to avoid suction of the pump is beneficial. Cardiac decompression is optimized by the active venous drainage.

Weaning from extracorporeal circulation is maintained by simple flow reduction. Separate retransfusion is no longer necessary.

Results: Because of the reduced priming volume as compared to standard extracorporeal circulation, hematocrit during cardiopulmonary bypass is significantly higher. The need for blood products could be reduced.

Discussion: The benefits and adverse effects of the nonocclusive Delta-Stream™ diagonal pump in the setup are discussed. First clinical results promise beneficial effects on the need for blood transfusions caused by reduced hemodilution.

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PUMPLESS EXTRACORPOREAL LUNG ASSIST (PECLA): TRANSFER OF CRITICALLY ILL PATIENTS

Background: The transport of patients with serious lung failure (resp. global insufficiency) due to polytraumatization specifically internistic base illness in the centres of maximal supply is on the one side for survival often an indispensable necessity but on the other hand represents a high risk measure. PECLA is an ideal solution for risk minimisation in this unstable phase.

Method: Six patients, who were transferred to the Regensburg University hospital, had at their first place of treatment a serious respiratory global insufficiency (FiO_2 1.0 and pO_2 36-57, pCO_2 56-104) so that transportation was considered to be an unacceptable risk. Therefore a PECLA was implanted by an emergency doctor and a cardioengineer on site. With a running PECLA the patients were transferred via intensive transport (2) and intensive transport helicopter (4) respectively. For the extracorporeal lung assist a bioline coated NOVABREATH® MO-oxygenator (Jostra AG) was used. The connection took place by means of a percutaneous 19Fr cannula in the Arteria and Vena femoralis.

Results: In 4 patients a serious ARDS in internistic base illness and in 2 patients lung failure after polytrauma was present. The mean age of the patients was 37.3 ± 13.5 years. The assist duration comprised on average 7.7 (2-22) days. 4 patients could be weaned off the system and without necessary oxygen therapy be returned to their local hospital. One patient died on the system and another one day after being weaned off the PECLA system due to circulatory failure.

Discussion: The transportability of patients with acute respiratory insufficiency could be set-up i.e., clearly improved through the implantation of the PECLA system in the transfer hospital. The logistic effort for this measure is relative small. The provision of specialists and special equipment offers the decisive advantage with regards to prognosis improvement and therapy optimization.

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