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UPDATED PEDIATRIC PERFUSION HANDOUT: 1997

We hope this handout will be taken as a reference. At this time our primes are in the high 100's ml for the neonate. If you include the cardioplegia & hemoconcentrator we are looking at the 250's ml. We pour the remaining blood cardioplegia into the system during the warming phase and continue hemoconcentrating to the maximum. Our tubing is weird but works for us if low primes are your priority. Techniques and modifications will follow sometime next month.

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ESSENTIALS FOR DECREASING PRIMES

1. Low Prime Products``````````
2. Smallest Tubing Size Possible
3. Shortest Tubing Length Possible
4. Hardware Size & Versatility

PRODUCTS

Membrane Oxygenators: Keep in mind that depending on various variables when routinely pushing MOs to the maximum rating, a bypass circuit to the blender system utilizing 100% wall oxygen is highly recommended. Blenders at times do not deliver an absolute pure 100% oxygen.

AVECOR (Formerly SCI-MED) 0600-2A, 0800-2A, & 1500-2A

Membrane Surface Area	0.6, 0.8, & 1.5 m^2
Membrane Material	Silicone Rubber
Structure Type	Spiral coil membrane envelope
I.D. & O.D.	1/4 "
Rated Blood Flow	1.0, 1.2, & 1.8 L/min.
Max. Gas flow	1.8, 2.4 & 4.5 L/min.
Heat Exchanger Surface area	Comes without Heat Exchanger
Blood Connectors	1/4 "
Prime Volume	90, 100, & 175 ml
Pressure Limits	
Compliance	5mmHg
Max. Blood press Drop	200-300 mmHg
Max. Blood outflow press drop	400mmHg
Max. TransMem Press	750 mmHg

Comments: Probably the best MO material in the marketplace. There is significant room for R & D(lower primes, vaccum ventilation, VR etc...) for improving their excellent product. There haven't been any major pediatric upgrades for a very very long time.

BENTLEY BABYVOX (Bumped by Baxter)

Membrane Surface Area	0.8m^2(10 channels)
Membrane Material	Polypropylene
Structure Type	Hollow Fiber
I.D. & O.D.	265 & 365 micron
Rated Blood Flow	2.5-3.0 L/min.

Heat Exchanger Surface area	1.0 m^2
Blood Connectors	1/4 "
Prime Volume	110 ml
Max. Gas flows	None
Potting Material	Polyurethrane

Comments: This product has all the makings of being one of most popular MOs in the field of pediatrics but it was dumped by Bentley.

COBE VPCML

Membrane Surface Area	0.40 m^2/0.85 m^2/1.25 m^2
Membrane Material	Polypropylene
Structure Type	Flat Sheet
I.D. & O.D.	NA
Rated Blood Flow	1.3/2.7/4.0 L/min.
Heat Exchanger Surface area	NR
Blood Connectors	3/8 "
Prime Volume	
1/3 Membrane	280ml(1/3 + membrane + 1/4" boot + HE)
2/3 Membrane	375ml(2/3 membrane + 3/8" boot + HE)
Combined	455ml(Both membranes + 3/8" boot + HE)
Membranes only	80, 140, & 220 ml(combined)
Max. Gas flows	None

Comments: Excellent product for the larger patients but our product for the neonates.

COBE PEDI OPTIMA(Currently pending FDA 510 K approval)

Membrane Surface Area	0.9m^2
Membrane Material	Polypropylene
Structure Type	Hollow Fiber
I.D. & O.D.	280 & 380 micron
Rated Blood Flow	3.0 L/min.
Heat Exchanger Surface Area	1.3m^2
Blood Connectors	3/8 "
Prime Volume	150 ml
Max. Gas flows	None
Potting Material	Polyurethrane

Comments: No estimated plans on release until FDA approves 510K. Integral Hardshell VR (Vol 2200mls). VR(bag) optional.

BENTLEY/MACCHI OXIM 06 & RV-08

Membrane Surface Area	0.6 m^2
Membrane Material	Polypropylene
Structure Type	Hollow Fiber
I.D. & O.D.	? micron
Rated Blood Flow	1.2 L/min.
Heat Exchanger Surface area	0.03 m^2
Blood Connectors	In 1/4" & Out 3/8 "
Prime Volume	125 ml
Max. Gas flows	None
Venous Reservoir max vol.	800 ml

* NA USA.

COBE MICRO

Membrane Surface Area	0.33 m^2
Membrane Material	Polypropylene
Structure Type	Hollow Fiber
I.D. & O.D.	? micron
Rated Blood Flow	0.8 L/min. (but you can push it easy to 1.0 or more with other variables)
Heat Exchanger Surface area	0.03 m^2

Blood Connectors	3/16” (1/4” tubing fits it very well)
Prime Volume	52 ml
Max. Gas flows	None
Venous Reservoir max vol.	400 ml

Comments: The lowest prime in the world. The hardshell reservoir works very well. It is a little weaker than the Lilliput for pO2 but the heat exchanger is great! Be sure to bypass the blender with absolute 100% oxygen when pushing the product in the vicinity of 1.1 - 1.3 liters/minute for the simple lesions with lower hcts.

MEDTRONIC MINIMAX PLUS

Membrane Surface Area	0.8 m^2
Membrane Material	Polypropylene
Structure Type	Hollow Fiber
I.D. & O.D.	400 & 460 micron
Rated Blood Flow	2.3 L/min.
Heat Exchanger Surface area	75.65 sq. in.
Heat Exchanger Prime	45 ml
Heat Exchanger metal	Aluminum with epoxy coating
Blood Connectors	3/8 "
Prime Volume	149 ml
Max. Gas flows	None
Potting Material	Polyurethrane

SORIN MASTERFLOW 34 & 51

Membrane Surface Area	0.42, 0.62 & 1.0 m^2
Membrane Material	Polypropylene
Structure Type	Hollow Fiber
I.D. & O.D.	240 & 290 micron
Rated Blood Flow	2L/min. & 3.5L/min.
Heat Exchanger Surface area	0.09
Blood Connectors	1.4"(2) & 3/8"(3.5)
Prime Volume	120 & 165 (34 & 51)
Max. Gas flows	3.5 L/min (34) 5.0 L/min (51)

Comments: Excellent product for the larger infant/toddler and up patients.

SORIN/DIDECO 4000

Membrane Surface Area	1.0 m^2
Membrane Material	Polypropylene
Structure Type	Hollow Fiber
I.D. & O.D.	280 & 380 micron(Midiflow)
Rated Blood Flow	4.0 L/min.
Heat Exchanger Surface area	0.11 m^2
Blood Connectors	3/8 "
Prime Volume	140 mls
Max. Gas flows	7.0 L/min

*NA USA Comments: Excellent product!

SORIN/DIDECO LILLIPUT

Membrane Surface Area	0.34 m^2
Membrane Material	Polypropylene
Structure Type	Hollow Fiber
I.D. & O.D.	280 & 380 micron
Rated Blood Flow	0.8 - 1.0 L/min.
Heat Exchanger Surface area	0.02 m^2
Blood Connectors	3/16" & 1/4"
Prime Volume	60 mls

Max. Gas flows	2.0 l/min

Comments: Excellent oxygenator for neonates with unofficial maximum blood flows up to 1200-1300 on simple defects. Excellent venous bag. For hardshell users we prefer the Medtronic pediatric minimax venous hardshell reservoir rather than the venomidicard. Between the Micro or the Lilliput it is a tough call to make depending if you are a closed versus a open system user.

TERUMO CAPIOX 308 & 320

Membrane Surface Area	0.8 m^2 & 2.0m^2
Membrane Material	Polypropylene
Blood Film	Inside
Structure Type	Hollow Fiber
I.D. & O.D.	200 & 250 micron
Rated Blood Flow	0.8 & 2.5 L/min.
Heat Exchanger Surface area	0.8m^2 / 0.16m^2
Blood Connectors	1/4 " & 3/8 "
Prime Volume	80ml & 200 ml
Max. Gas flows	None

Comments: A workhorse starting from the original 08 model to the current 308. Very reliable and trustworthy but cannot be pushed beyond 5.5 kilos especially with high hcts. No neonatal hardshell reservoir.

TERUMO PEDI SX

Membrane Surface Area	1.0m^2
Membrane Material	Polypropylene
Wall thickness	50 microns
Blood Film	Outside
Structure Type	Hollow Fiber
Rated Blood Flow	4.0 L/min.
Heat Exchanger Surface area	0.8m^2 / 0.16m^2
Blood Connectors	3/8 " (with ¼" quick connector adapters)
Prime Volume	135ml
Max. Gas flows	None

Comments: Harshell and bag reservoirs available. Excellent product. Not used by us in the neonatal arena because of the much lower neonatal oxygenators in the marketplace.

Reservoirs

Our preference is for open system hardshell reservoirs because of the high incidence of venous air encountered in the pediatric field. The following are the very few open systems allowed in the USA with some upcoming models currently used internationally. The new Terumo pedi venous reservoir appears to be a wonderful addition to the pediatrics. But for the neonate the **MICRO** from Polystan distributed by Cobe is the way to go!

Arterial Filters: Use of AFs in the field of pediatrics various significantly among institutions. Our opinion is that the only reason for using AFs is if Leukocyte filtration(Pall Leuko-Guard) is believed worthwhile by the insitution. We as well as many centers exclude AFs when MOs are utilized unless BOs are used. **We do not utilized arterial filters with membrane oxygenators**. One can use the low prime 33-50ml arterial filters from Terumo/Dideco/Pall for the neonate population.

Hemoconcentrators: We utilized hemoconcentrators on all our cases. These products combined with our low primes allow us to achieve very good hcts. Prior to coming off CPB.

Product	Prime	Ports	Surface Area	Patient (Kgs)	Ultrafiltration Rate(ml/min.)
Minifilter Plus™	15 ml	1/8"	0.08 m^2	less than 5 kgs	2-6
#Dideco Pedi	22 ml	3/16"	0.2 m^2	less than 15 kgs	5-25

Hemocor Plus 400	27ml	1/4"	0.3m^2	less than 20 kgs	9-34

#Outside USA in near future

Cardioplegia Systems

In pediatrics, cardioplegia systems can be customized utilizing modifications of tubing sizes, reservoirs, alarms and adapters for decreasing the total system prime while offering safety to the patient. Presently, our lowest prime custom system with excellent efficiency is the utilization of the **Sarns conducer(7ml)** + the Gish recirculation **table line** + **reservoir(burrette**) with a minimal prime of 40 mls. Currently, Sorin offers a pediatric one pass system utilizing the BCD. The same tubing circuit replacing with a smaller heat exchanger can lower the prime another approx. 40 mls. With a one pass system (excluding reservoir & recirculation line) it can be lowered to a total primwe of approximately 30-40 mls. It is our hope Sarns will start with a pediatric cardioplegia system because of their lowest prime & efficient heat exchanger in the current marketplace.

The one pass systems out there are very good but not our first choice. They simply take up too much prime. If your goal is low primes than one pass systems should be used only as a last resort.

Cardioplegia Boot Choices

The following tubing sizes can offer the pediatric perfusionist lower primes while offering a more uniform type of volume infusion especially with the smaller child.

1/8" I.D. 3.5ml/revolution	5/32" I.D.5ml/revolution
3/16" I.D. 7ml/revolution	1/4" I.D.13ml/revolution

Tubing Size	Pt. Size
1/8" x 1/16"	<5 kilos
3/16" x 1/16"	6-25 kilos
1/4" x 1/16"	>25 kilos

CELL-SAVERS IN PEDIATRICS: Not used in our cases. Our preference is for hemoconcentrators.

TUBING

PVC tubing comes from the family of thermoplastics. In addition to itself other family members are polyethylene, polypropylene, acrylics, nylons, polyurethanes, polycarbonates, fluorocarbons, polysulfones, cellulosics and silicone rubbers. PVC is the most yielding of thermoplastics.

PVC tubing starts with an originial monomer. Combined with an added catalyst can be in a liquid or gaseous state. The polymerization include chemical reactions caused by the addition of a catalyst, heat and agitation. Final product is a viscous polymer. This viscous vinyl is cool with water and other by-products evaporated filtered, dried or squeezed out.

Additives to the polymer are added to reach the desire end product in pellets. These additives may include:

Plasticizers-used to make rigid polymers more flexible

Fillers-used to change the property of the polymers

Extenders-used to "amplify" the volume of the plastic; less cost

Colorants-dyes, organic & inorganic dyes

Stabilizers-stablized polymer, easier to extrude, improve UV light & general weathering resistance

Lubricants & mold release agents-make extrusion/molding easier

Polymer + fillers + colorants + stabilizers + extenders + plasticizers = PVC pellets

The next step is the actual extrusion. This is the process of forcing the PVC pellets through a die to produce the tubing. These pellets are fed from a hopper into a hot cylinder. Heat softens the material and forces it by a spiral screw through a cylinder and out through a die opening. The tubing is cooled, hardened and cut to desired lengths.

Usual Properties of Extracorporeal PVC Tubing:

Color	Crystal Clear
Durometer Hardness	60's to 80's
Tensile Strength, psi	2000 to 2700
Low Temperature Range	Flexible at 0^oF to 10^oF
	Brittle at -55^oF to -25^oF

	(-48°C) to (-31°C)
High Temperature Range Maximum Recommended Operating Temperature	180°C to 185°C
Elongation%	360 to 350

Sterilization can be by: Steam, Ethylene Oxide, Gamma or Electron Beam Radiation

Extracorporeal tubing was first rated as Class VI during the early 1970's by one of the leading extracorporeal companies which is well known to us (Tygon/Norton). The Class VI guidelines during these times were accepted by the FDA in 1976. To be rated as Class VI, there needs to be a series of testing that needs to be done by all tubing companies.

This series of extraction testing is done with various solutions and the use of mice & rabbits. The four test solutions are saline, saline/ 5% ethyl alcohol, cotton seed oil and polyethylene glycol 200(high ETOH content). Some of the solutions are injected into mice at different locations and examined for adverse reactions. Some of the testing is for placing samples under the skin of rabbits and checking for adverse reactions. Most of the testing is done by outside contract biomedical toxicology laboratories.

Our perfusion companies make or purchase PVC tubing from contract tubing manufacturers. All companies offer the basic sizes for their customers. Clinically available extracorporeal tubing by Tygon(which probably has the largest selection in stock) to the perfusionist are the following:

Once knowing the maximal rating of PVC tubing in the clinical setting, informed decisions on size of circuits can be made. This allows for appropriate selection for all patients in the pediatric arena and its classification which follows. For most complex cases our arterial tubing "boot" preference is for rpms in the 60 to 90 range with rpms up to 150s for simpler cases. Again knowing the ml/rpms permits appropriate selection of arterial "boot" selection to best suit the patient.

Maximum Arterial Line Size for Calculated Blood Flows

Tubing Size	Max. Arterial Flows (Consider VARIABLES!)
1/8"	<450 ml/min.
5/32"	<750 ml/min.
3/16"	<13000 ml/min.
1/4"	<3000 ml/min.
5/16"	<5500 ml/min.
3/8"	>5000 ml/min.

Maximum Venous Line Size Range for Calculated Blood Flows

Tubing Size	Max. Ven. Return (Consider VARIABLES)
3/16"	<500-650 ml/min.
1/4"	<1200-1600 ml/min.
5/16"	<1800-2300 ml/min.
3/8"	<4000-4500 ml/min.
7/16"	<5000-5500 ml/min.
1/2"	>5000 ml/min.

Approximate Tubing Primes & Max. Blood Flow Rates(65 durometer)

2/32" I.D.	0.6ml/ft.
3/32" I.D.	1.8ml/ft.
1/8" I.D.	3.5ml/revolution(2.5 ml/ft.)
5/32" I.D.	5ml/revolution(3.7 ml/ft.)
3/16" I.D.	7ml/revolution(5 ml/ft.)
1/4" I.D.	13ml/revolution(9.65 ml/ft.)
5/16" I.D.	18ml/revolution(13.5 ml/ft.)
3/8" I.D.	27ml/revolution(21.71 ml/ft.)
7/16" I.D.	38ml/revolution(28.5 ml/ft.)
1/2" I.D.	45ml/revolution(38.61 ml/ft.)

5/8" I.D.	65ml/revolution(55.77 ml/ft.)

Tubing Connection Recommendations:

When using odd size tubing modifications, manual expertise has to be developed for odd size connections.

Tubing size	Connector
1/8"	#Lare bore luer or *3/16"
5/32"	*3/16"
3/16"	#3/16" or 1/4"
5/16"	#1/4" or *3/8"
7/16"	#3/8" or *1/2"

Low pressure connection * High pressure connection

CLASSIFICATION OF EXTRACORPOREAL TUBING CIRCUITS

The following arterial boot classification and variables are used by us to define our circuits. Tubing selection is straight forward except when it come to borderline areas. It is in this area where one has to decide whether the larger arterial or venous would be a better choice. It is in this area where the variables are taken into consideration for deciding on the selection of tubing.

Example #1: 13 kg ASD, Secundum- simple case with only hemodilution(low viscosity) required. Selection for IV, B_4 T_1 L_1 C_2 (3/16"/1/4" AV loop) would be fine especially when only hemodilution(no blood transfusion) & mild hypothermia(low viscosity) is to be utilized. Depending which system is used, hcts should be in the range of 24 to 28 on CPB (assuming no severe anemia) with no problems encountered. The T_1 L_1 C_2 demonstrates rectal temp. between 32^{o}C-36^{o}C, under 1 hour CPB and bicaval cannulation.

Example #2: 13 kg DORV/PS/VSD/s/p LBT- complex case with a desired hct. of mid-20's during hypothermia(25^{o}C R). During warming, a desired hct of mid-30's or higher. In this case selection for VI, B_5, T_3 L_3 C_2 would be our choice. The variables here are deep hypothermia & length of case (2-3 hours). Selection of 1/4" arterial loop line is chosen because of the degree of hypothermia & higher hcts during warming increasing to the viscosity(lower pressures over 3/16") as in this borderline case. With more hypothermia, especially in borderline cases venous return decreases requiring a larger size venous line for adequate venous drainage. For long cases over one hour we prefer to keep our RPMs under 90 rpms during the case. In this case, 5/16" tubing would be in the 60-90 RPM/minute range. The T_3 L_3 C_2 demonstrates rectal temp. of 25oC, between 2 to 3 hours CPB and bicaval cannulation.

ARTERIAL BOOT CLASSIFICATION

1 - 1/8"	4 - 1/4"	7 - 7/16"
2 - 5/32"	5 - 5/16"	8 - 1/2"
3 - 3/16"	6 - 3/8"	9 - 5/8"
	C - Centrifugal	

VARIABLES

Temperature (RECTAL) (Hypothermia C^{o})	Length (Hours)	Cannulation Technique
1 - Mild(36-32^{o})	1 - (< 1 hour)	1 - Single
2 - Moderate(31-26^{o})	2 - (< 2 hours)	2 - Bicaval
3 - Deep(25-19^{o})	3 - (< 3 hours)	
4 - Profound($\leq$$18^{o}$)	4 - (> 3 hours)	

CLASSIFICATION OF EXTRACORPOREAL TUBING CIRCUITS

A / V Loop Size[1]	Arterial Boot Size[1,2]	Degree of Hypothermia	Length of Case	Cannulation Technique
		V A R I A B L E S		
(I - IV)	(B)	(T)	(L)	(C)

I.	1/8" x 3/16"	2	1-mild	1-short	1-single
		3	2-moderate	2-medium	2-bicaval
		4	3-deep	3-long	
			4-profound	4-XL	
II.	5/32" x 3/16"	3	1-mild	1-short	1-single
		4	2-moderate	2-medium	2-bicaval
		C	3-deep	3-long	
			4-profound	4-XL	
III.	3/16" x 3/16"	3	1-mild	1-short	1-single
		4	2-moderate	2-medium	2-bicaval
		C	3-deep	3-long	
			4-profound	4-XL	
IV.	3/16" x 1/4"	4	1-mild	1-short	1-single
		5	2-moderate	2-medium	2-bicaval
		C	3-deep	3-long	
			4-profound	4-XL	
V.	1/4" x 1/4"	4	1-mild	1-short	1-single
		5	2-moderate	2-medium	2-bicaval
		6	3-deep	3-long	
		C	4-profound	4-XL	
VI.	1/4" x 5/16"	5	1-mild	1-short	1-single
		6	2-moderate	2-medium	2-bicaval
		C	3-deep	3-long	
			4-profound	4-XL	
VII.	1/4" x 3/8"	6	1-mild	1-short	1-single
		7	2-moderate	2-medium	2-bicaval
		C	3-deep	3-long	
			4-profound	4-XL	
VIII.	5/16" x 3/8""	6	1-mild	1-short	1-single
		7	2-moderate	2-medium	2-bicaval
		8	3-deep	3-long	
		C	4-profound	4-XL	
IX.	5/16" x 7/16"	6	1-mild	1-short	1-single
		7	2-moderate	2-medium	2-bicaval
		8	3-deep	3-long	
		C	4-profound	4-XL	
X.	3/8" x 3/8"	6	1-mild	1-short	1-single
		7	2-moderate	2-medium	2-bicaval
		8	3-deep	3-long	
		C	4-profound	4-XL	
XI.	3/8" x 1/2""	6	1-mild	1-short	1-single
		7	2-moderate	2-medium	2-bicaval
		8	3-deep	3-long	
		9	4-profound	4-XL	
		C			
XII.	3/8" x 5/8"	6	1-mild	1-short	1-single

7	2-moderate	2-medium	2-bicaval
8	3-deep	3-long	
9	4-profound	4-XL	
C			

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1 Selection depending maximum rated blood flows and variables

2 RPM range from 60 to 120 dependent on variables

CANNULAS

It is imperative as well to know the maximal flows of our aortic & venous cannulas. Once calculated blood flows are undertaken selectiion of arterial, venous cannulas & vents can be recommended to the surgeons. At times one needs to use smaller size cannulas because of the particular anatomy encountered during the cases. Under this conditions, appropriate modifications of techniques & conduct of perfusion must be undertaken to best suit the patient.

Aortic Cannulas

Non Metal Tip	***Maximal Flows***
8F	*< 750 ml/min.*
10F	*< 1100 ml/min.*
12F	*< 2100 ml/min.*
14F	*< 3100 ml/min.*
16F	*< 4200 ml/min.*

Venous

Metal Tip Right Angle	Maximal Flows	Non Metal Straight	Maximal Flows
3.8mm(12F)	300 ml/min.	14F	300 ml/min.
4.5mm(14F)	600 ml/min.	16F	500 ml/min.
5.2mm(16F)	900 ml/min.	18F	700 ml/min.
6.0mm(18F)	1200 ml/min.	20F	1100 ml/min.
6.5mm(20F)	1500 ml/min.	22F	1500 ml/min.

Companies: Argle, DLP, Research ,Sorin ,USCI(Bard)

Ventricular Vents

8F	< 3 kgs
10F	< 10 kgs
13F	< 18 kgs
14F	< 22 kgs
16F	< 35 kgs
20-22F	> 35 kgs

Companies: Argle, DLP, USCI(Bard)

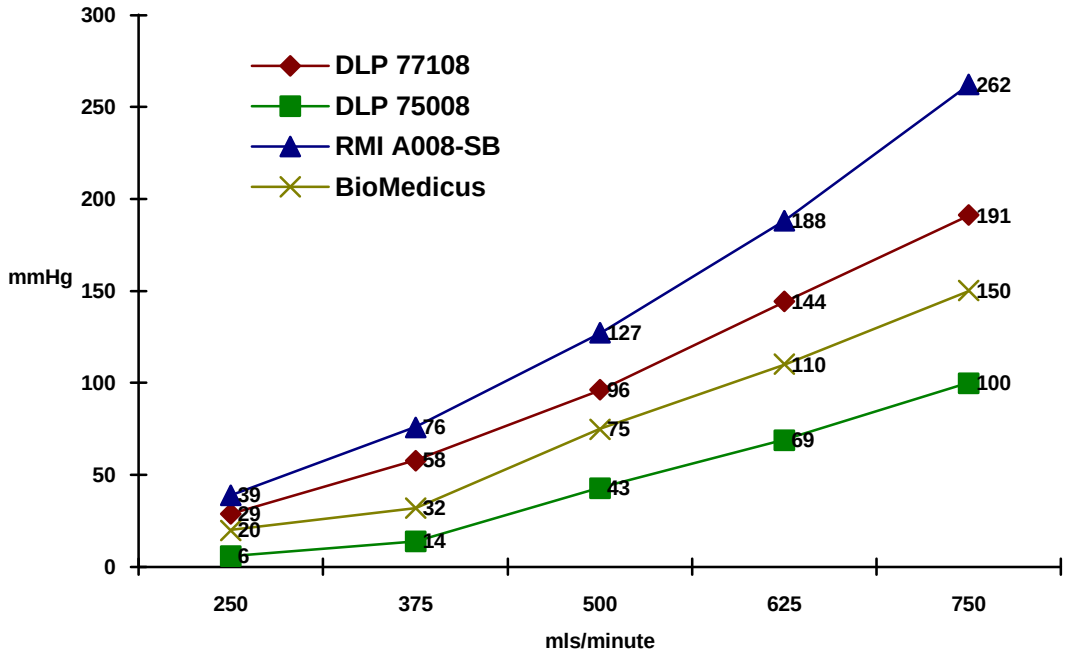
Cardioplegia needles: Are very variable. We use Angiocaths, TMP & DLP types.

Aortic cannulas lab studies:

At the time these test were done with outdated human blood, DLP 75000 series has the lowest pressure drops when compared to the other DLP 77000, Bio-Medicus and RMI aortic cannulas. ***Just recently, we tested the new improved pediatric aortic cannulas from RMI. They appear to have slightly low pressure drop on the straight ones and slightly higher pressure drop on the right angle ones. We hope to have them ready in late 1997.***

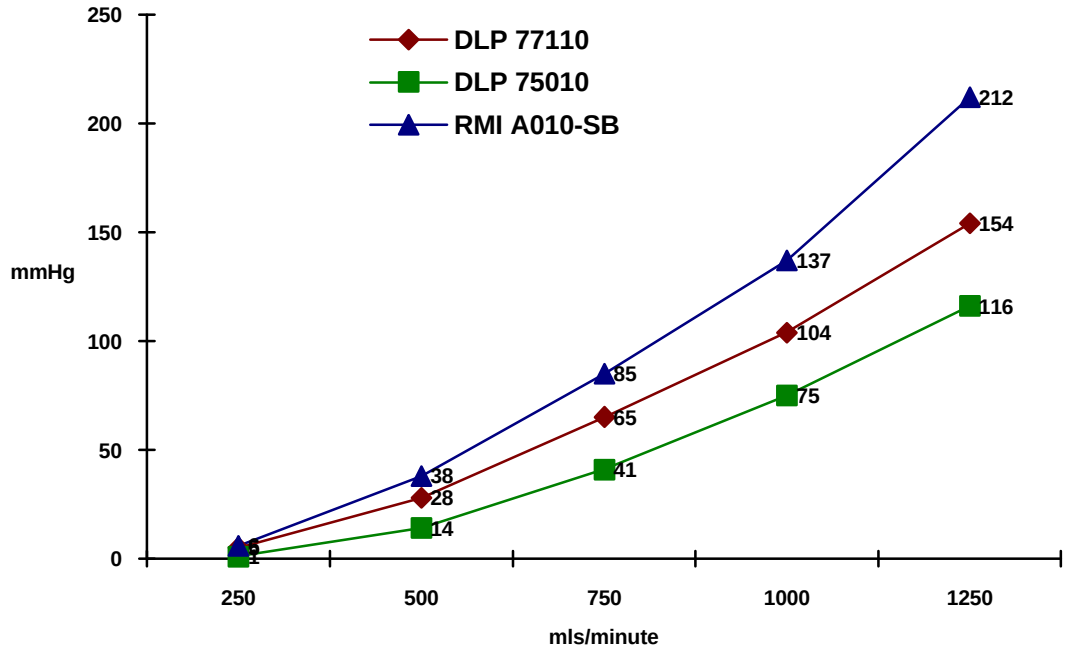
AORTIC CANNULAS: 8 FRENCH

Hct : 40% Temp: 37ºC



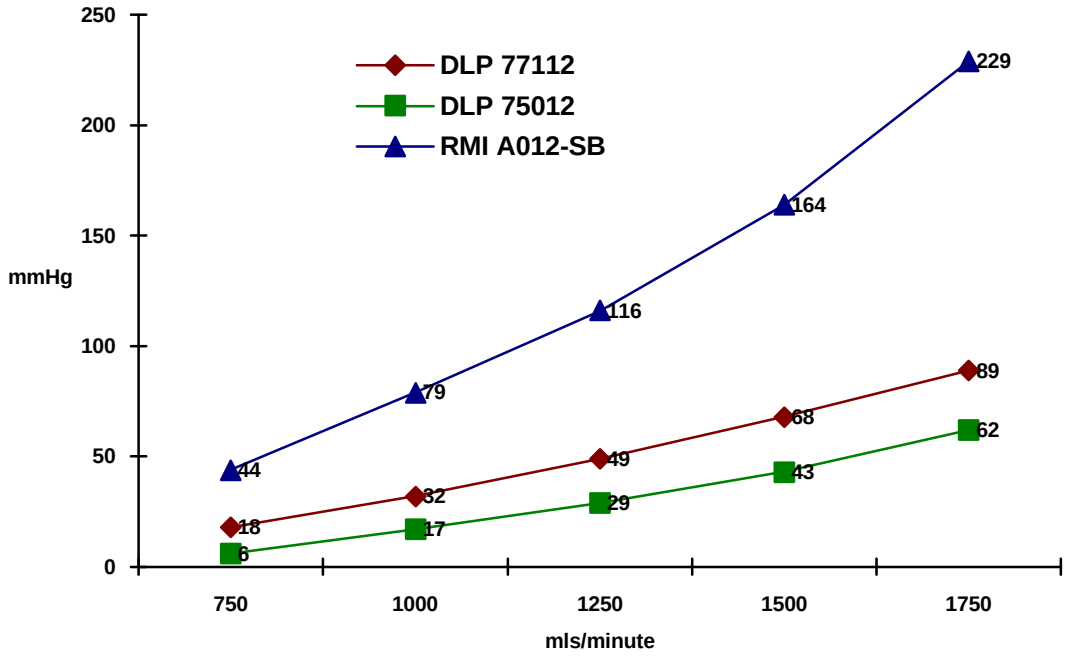
AORTIC CANNULAS: 10 FRENCH

Hct : 40% Temp: 37ºC



AORTIC CANNULAS: 12 FRENCH

Hct : 40% Temp: 37ºC



HARDWARE Heart Lung Machine for Pediatrics:

Our preference is the COBE heart lung machine. The main reason is the alarm systems which we feel are the best for pediatrics at this time. The universal capability of the system is its main strong assest. The alarms systems work with tubing as small as and weird as 3/16", 5/16" and 7/16" . We use one for the arterial and the cardioplegia system.

Centrifugal Pumps: Further research is needed in the pediatric field. At this time most centers are using them for left heart bypass or liver bypass. On the ECMO cases they are used usually for patients over 20kgs. The main concern is still hemolysis. Many pediatric perfusionists at this time have very strong concerns about centrifugal pumps. There are some that really believe in them. I'm sure Medtronic can be of some assistance on some references in pediatrics.

Hemodilution Calculations(the old but simple formula everybody can use)

RCV = Patient blood volume x Hct. TBV = Total body volume

Added RCV Vol. = PRBC'S x 0.70

$$\frac{\text{RCV}}{\text{TBV + Pump Volume}} = \text{PUMP HCT.} = \frac{\text{RCV + Added RCV Vol.}}{\text{TBV + Prime Vol.}}$$

FORMULAs for BSA or use nomogram These are two formulas which can be used to calculate BSA. Or one can simply use the nomogram Our choice is for the square root of (kgs x ht)divided by 3600:

Body Surface Area(BSA) = ($Kg.^{0.5378}$)($Cm.^{0.3964}$)(0.02465)

or

Square Root of: kgs. x ht. (cms) ÷ 3600

This is our table to assist the surgeon determine whether a transannular patch for TOFs are needed or not. It has been very helpful to us for about 14-15 years now. There are other tables out there this is but only one reference source.

Table for minimal pulmonary annulus for TOFs/PSs utilized for deciding on whether transannular patch is to be undertaken:

BSA(m^2)	Diameter(mm)
0.4	10
0.5	11
0.6	13
0.7	14
0.8	15
>0.9	16

Standard Medication Drips

Amrinone---Positive inotrope & vasodilator with little chronotropic activity
Brand Name: Inocor
Dosage: Initial bolus of 0.75mg/kg I.V. then infusion of 5-10 micrograms/kg/min.
Use: Low C.O. syndrome, adjunctive therapy of PAH.
This drug increases C.O. due to its inotropic and vasodilator actions. Decreases LAP and total vascular resistance.

Dobutamine----Adrenergic Agonist Agent; Sympathomimetic
Brand Name: Dobutrex
Dosage: 2-15 micrograms/kg/min.
Use: Low C.O. syndrome
This synthetic catecholamine similiar to isoproterenol. Effect on the myocardium increases myocardial contractility with minimal peripheral vascular effects. It has less chronotropic effect than isoproterenol and doesn't stimulate the release of endogenous catecholamines without dopaminergic effects. It may be better than dopamine because of increasing C.O. with less effect on heart rate, SVR & PVR. Especially in pediatrics, it increases C.O., decreases LAP & SVR, and increase in heart rate.

Dopamine---Adrenergic Agonist Agent; Sympathomimetic
Brand Name: Dopastat/Intropin
Dosage: See below
Use: Adjunct in the treatment of shock which persists after adequate fluid volume replacement; dose related inotropic and vasopressor effects; stimulates dopaminergic, beta and alpha receptors. A possible adverse effect is the tendency to increase PVR.

Increase Renal perfusion:	Incr. C.O.	Incr. BP, SVR, HR
1 - 5 microgr/kg/min.	5 - 10 microgr/kg/min.	10 - 20 microgr/kg/min.

Epinephrine---Adrenergic Agonist Agent; Antidote, Hypersensitivity; Racemic Epinephrine
Brand Name: Adrenalin
Dosage: 0.1 - 1 microgr/kg/min.
Use: Bronchospasms; anaphylactic reactions; cardiac arrest/low C.O. syndrome

Isoproterenol---Adrenergic Agonist Agent; Bronchodilator; Sympathomimetic
Brand Name: Isuprel
Dosage: 0.01-.1 microgr/kg/min.
Use: Asthma/ COPD; A-V nodal block; hemodynamically compromised bradyarrhythmias or atropine-resistant bradyarrhythmias or atropine-resistant bradyarrhythmias, temporary use in 3rd degree heart block; low C.O.; vasoconstrictive shock states

Milrinone-Positive inotrope & vasodilator with little chronotropic activity. Much like Amrinone.
Brand Name: Primacor
Dosage: 0.5 mcgs/kg/min.
Use: This drug increases C.O. due to its inotropic and vasodilator actions. Decreases LAP and total vascular resistance.

Nitroglycerin---Antianginal Agent; Antihypertensive; Nitrate; Vasodilator; Vasodilator, Coronary
Brand Name: Tridil
Dosage: 0.5 - 2 microgr/kg/min.
Use: Angina pectoris; CHF with M.I.; PAH; hypertensive emergencies.

Nitroprusside Sodium---Antihypertensive; Vasodilator
Brand Name: Nipride
Dosage: 1 -10 microgr/kg/min.
Use: Management of hypertensive crises; CHF
There is dilation of both arterial & venous capacitance vessels with quick onset of action as well as a short duration. With continuous infusion precise control of its hemodynamic effects is workable. CV effects are the combination of venous pooling know as *decreased preload* and arteriolar vasodilation known as *decreased afterload*. When LV impairment is present, afterload reduction effects prevail giving better myocardial function and C.O. There also is useful effects on the pulmonary circulation. The dilation of the pulmonary vascular system reduces the afterload of the right ventricle when PAH is present.

Prostaglandin E_1---Prostaglandin
Brand Name: Prostin VR Pediatric
Dosage: 0.01 - 0.4 microgr/kg/min.
Use: Temporary maintenance of patency of ductus arteriosus in neonates with ductal-dependent congenital heart disease until surgery can be performed. These defects includes cyanotic and acyanotic heart disease.

Phenylephrine Hydrochloride---Adrenergic Agonist Agent; Sympathomimetic
Brand Name: Neo-Synephrine
Dosage on CPB: 5 - 20 microgr/kg/dose every 10 to 15 minutes prn
Use: Treatment of hypotension

Drug Effects	Receptor Site	PVR	SVR	MAP	SBP	DBP	HR	CO	LAP/PCW
Amrione (Inocor) 5-10mcg/kg/min. (Load 0.75-1mg/kg)	Inhibit phosphor diesterase	↓	↓	↓	↓	↓	↑	↑	↓
Dobutamine (Dobutrex) 2-15mcgs/kg/min.	$B_1>B_2=A$	↓	↓	↑	↑	↓	↑	↑	↓
Dopamine (Dopastat/Intropin) 2-15 mcgs/kg/min.	Dop/B_1	↓	↔	↑	↑	↑	↑	↑	↑
Epinephrine (Adrenalin) 0.01-1mcg/kg/min.	B>A	↓	↓	↔	↑	↓	↑	↑	↑
Isoproterenol (Isuprel) 0.1-1.0 mcg/kg/min.	B	↓	↓	↓	↑	↓	↑	↑	↓
Milrinone (Primacor) 0.5mcgs/kg/min. (Load 50mcg/kg)	Inhibit phosphor diesterase	↓	↓	↓	↓	↓	↑	↑	↓
Nitroglycerin (Tridil) 0.5-2mcgs/kg/min.	Lowers venous inducers	↔	↓	↓	↓	↓	↔	↑	↓
Nitroprusside (Nipride) 2-15 mcgs/kg/min.	cGMP	↓	↓	↓	↓	↓	↔	↑	↓
Phenylephrine (Neo-Synephrine) 5-10 mcg/kg/dose	A	↑	↑	↑	↑	↑	↓	↓	↑

↓----Decrease **↑----Increase** **↔----Same**

Others:

CaCl 10% drip dose = (1.36 mEq/ml or 0.68 mmmoles/ml) 0.03 - 0.12 cc/kg/hr. [0.04-0.016 mEq/kg/hr or 0.02-0.08 mmoles/kg/hr)

Prostaglandin E_1 (PGE_1) = PDA patency & ↓PVR; 0.01 - 0.4 mcgs/kg/min.

FACTORS ALTERING PULMONARY VASCULAR RESISTANCE

↑ INCREASE ↑	↓ DECREASE ↓
Hypoxia	Oxygen
Hypercarbia	Hypocarbia
Acidosis	Alkalosis
Sympathetic stimulation	Tolazoline
Increased pulmonary blood flow	Nitroprusside
Elevated airway pressure	Nitroglycerin
Pulmonary emboli	Prostaglandin E1
Hypothermia	Isoproterenol
	Dobutamine
	Amrinone

Drug Calculations for Catecholame Drips (for the boards)

Mgs ÷ cc in Bag/syringe

x 1000 (to change to micrograms)

÷ wt in kgs (to change to per kilo calculation)

÷ 60 minutes (to change per minute)

X hourly rate (cc /hr)

mcg/kg/minute

The opinions of this handout solely belong to Jorge Molina & Ron Gorney from Pediatric Cardio-Thoracic Surgery Associates and are to be used only as a reference.