Anesthetic Management for Cardiac Surgery without Transfusion

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“Transfusion is transplantation”

	RBC	platelet	Bone marrow	organ
Major antigens	ABO	HLA,(ABO)	HLA	ABO, HLA
Organ procurement	Easy	Easy	Relatively easy	Major surgery
Immunosuppression	No	No	Required	Required
Transplantation effectiveness	Very effective	Relatively effective	Variable	Variable

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Hemoglobin (Hb), as a Transfusion Trigger

For over 40 years,

"10/30 rule“

Hb 10 g/dL & Hct 30 %

Consensus, Task Forces

NIH Consensus Conference on Periop RBC Transfusion

multiple factors of pt's clinical status & O2 delivery:

risks of anemia VS. risks of transfusion

7g/dL (21%) as an indication for transfusions

10g/dL (30%) transfusion usually is unnecessary

(*JAMA 1988;260:2700-3*)

ASA Task Force on Blood Component Therapy

O2 delivery is maintained in most at 7g/dL

transfusion is rarely needed if > 10g/dL

almost always needed at < 6g/dL

(*Anesthesiology 1996;84:732-47*)

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Consensus, Task Forces

The Canadian Expert Working Group, transfusion for adults & children

few pts have signs or symptoms 7-8 g/dL

weakness at 6g/dL

dyspnea at rest occurs at 3g/dL

CHF at 2-2.5g/dL

The College of American Pathologists' guideline

transfusions to minimize Sx at Hb of 5-8 g/dL

(Arch Pathol Lab Med 1998;122:130-8)

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Consideration for Special Religious Group

Pts refusing transfusions on religious grounds:

Rare deaths by anemia at Hb > 5g/dL

(*Transfusion 1994;34:396-401*)

Jehovah's Witness patients

"30-day mortality rate"

1.3% preop Hb > 12 g/dL

33% preop Hb < 6 g/dL

(*Lancet 1996;348:1055-60*)

The death rate was 4.3-fold higher in pts with cardiovasclar disease (This finding was not replicated when the same investigators evaluated consecutive pts repairing fractured hips)

almost all pts received transfusions when Hb < 8g/dL

(*JAMA 1998;279:199-205*)

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Consensus, Task Forces

Strategies for meeting on-going transfusion needs

(1) assessing anemia-related Sx

(2) determining signs or Sx alleviated by transfusion

(3) specifying minimal Hb with satisfactory organ function

(4) evaluating the risk VS benefit ratio for transfusion

(Can Med Assoc J 1997;156:S1-24)

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Adaptive Mechanisms for Anemia

Combination until Hb 1/2-3 of normal value

↑ CO, HR &/or SV

DO_2 = Cardiac output x CaO_2

Hb-bound O_2 & dissolved O_2

(1.39 Hb x CaO_2) + (PaO_2 x 0.0031)

redistribution of blood e.g., shunting blood

↑ O_2 carrying capacity of RBC

2,3-DPG, O_2 off-loading by up to 18%

A large redundancy in O_2 delivery/consumption at rest

Intravascular volume → & Hct ↓(< 10 %)

= arterial O_2 content↓

O_2 delivery will be theoretically adequate by

- ↑ cardiac output,
- Rt shift of the O_2-Hb dissociation curve
- O_2 extraction ratio↑

Adaptive mechanisms may be less efficient in coronary artery narrowing or tachycardia

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Anemia & Heart

The heart: more O_2 delivery-dependent than other organs

myocardium O_2ER = about 50%

In normal, if myocardial work ↑

↑DO_2 majorly via ↑ coronary blood flow

In anemia with healthy heart till Hb 3-4 g/dL,

both ↑ blood flow & ↑ O_2 ER to myocardium,

ischemia occurs after reaching Hb 3-4 g/dL

Anemia in Critically ill Patients

O_2 utilization becomes pathologically DO_2-dependent;

arterial lactate ↑

a change in the slope of O_2 ER

Indicators of poor tissue perfusion

arterial lactate↑

an O_2ER > 0.3

a DO_2 < 10-12 mL/kg/min

SvO_2 ↓ $ScvO_2$↓

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Various Transfusion Triggers

- Hb
- PvO_2:
  reflects ts. oxygenation
  underestimates the level of hypoxia
- SvO_2 (or $ScvO_2$)
  tissue O2 level
  decline rapidly at Hct < 20%
  clinically meaningful at < 55% in CV surgery
- VO_2
- O_2 Extraction Ratio
- Lactate
- Regional cerebral O_2 saturation (cerebral oximetry)

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JWs, & the Watchtower Bible & Tract Society (WTS)'s policy in transfusion

- The revised policy continues to prohibit of blood, namely red cells, white cells, platelets & plasma.
- This policy lacks any meaningful basis for a Christian since the bible does not define what a primary or secondary component of blood is & seems to reflect the fact that blood banks commonly separate blood in this manner.
- It must be noted, however, that many of the blood components permitted by the WTS are considered to be major or primary by doctors & scientists
- With this classification, the major & primary components:

  water(80%), Hb(15%), albumin(2-3%), & globulin (1-2%)
- This classification would have prohibited the use of Hb-based blood substitutes & albumin as a plasma expander, which are now permitted to be used for Witnesses.

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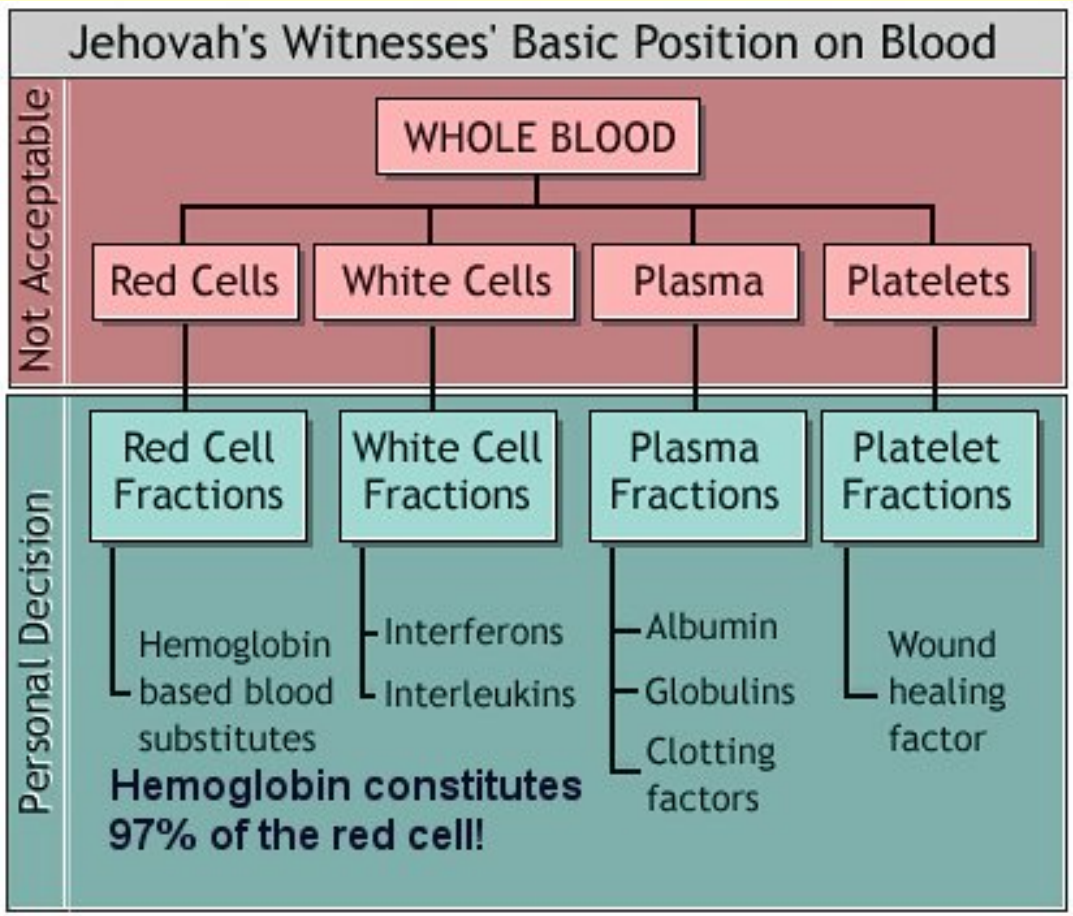
Watchtower Blood policy in 2006:

"...when it comes to fractions of any of the primary components, each Christian, after careful and prayerful meditation, must conscientiously decide for himself."

(The Watchtower 2000; June 15:29-31)



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Current policy & practice of WTS on prohibited & acceptable treatments	
Prohibited	Acceptable
· Whole blood	· Plasma proteins (albumin, globulin, fibrin)
· Red blood cells	· Clotting factors
· Platelets	· Stem cells
· Plasma	· Hemodilution, cell saver
· Hemoglobin solution	· Bone marrow transplants
· Stored autologous blood	· Extracorporeal circulation (heart-lung machine, dialysis, plasmapheresis)
· Blood donation	· Use of donated blood (to take acceptable components)

Table *Complex conditions that make similar components/procedures acceptable or unacceptable*

	JWs May Not Accept	JWs May Accept ....
Whole blood	IF taken as "blood transfusion"	IF taken as contained in bone marrow transplants
Plasma proteins	IF taken together as "plasma"	IF taken separately as individual blood component (albumin, globulin, clotting factors, fibrin)
White blood cells	IF taken as "white blood cells"	IF taken as "peripheral stem cells"
Autologous blood	IF tube connection to the patient's body is interrupted	IF tube connection to the patient's body is maintained (hemodilution, cell saver)
	IF it is stored	IF taken as "peripheral stem cells" (even if it is stored)
Stem cells	IF taken from umbilical cord blood[7]	IF taken from peripheral blood or bone marrow
Major protein from prohibited component	IF taken from red blood cells (hemoglobin)	IF taken from plasma (albumin)
Heart-lung machine	IF patient's blood is used to prime the machine	IF patient's blood is used to circulate in the machine
Epidural blood patch	IF blood is removed from vein and injected	IF injecting syringe is connected to vein via tube
Blood donation	IF donated by JWs for use of JWs and others	IF donated by non-JWs for use of JWs and others

Not prohibited but are not promoted Procedures

- Blood donation strictly for purpose of further fractionation
- Transfusions of autologous blood part of a "current therapy"
- Acute normovolemic hemodilution (ANH)
- Intraoperative cell salvage (ICS), autologous
- Heart-lung machine
- Dialysis
- Epidural Blood Patch
- Plasmapheresis
- Labeling or Tagging, blood is withdrawn, mixed with medicine, and then returned to the patient by transfusion

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Not prohibited but are not promoted Blood Products

Platelet Gel, blood is withdrawn & put into a solution rich in platelets & white blood cells

Fractions from RBC: Hb

Fractions from WBC: interferon, interleukin

Fractions from platelets: platelet factor IV

Fractions from blood plasma: albumin, globulin, Clotting factors, VIII & IX

Erythropoietin (EPO): 600 unit/kg & 300 unit/kg

PolyHeme™ chemically modified human Hb (500 ml/unit, containing 50 g Hb)

HemoPure™ chemically stabilized bovine Hb

rVIIa (recombinant factor VIIa)

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Erythropoietin (EPO)

a potent stimulant of erythrocyte production & development

augmenting presurgical autologous blood donations

in surgical patients with & without donations of autologous blood, as a means of limiting anemia & hastening postsurgical recovery of Hb.

Unfortunately, with few exceptions, the results are disappointing, in that most trials of EPO given prior to surgery do not result in reduction of allogeneic blood transfused, although most have documented a positive impact on reticulocyte count & preoperative Hct

Blood Substitute & EPO in a Severely Injured Jehovah's Witness

A 44/F Jehovah's Witness (*NEJM 2002; 346: 1097-98)*

motor vehicle collision

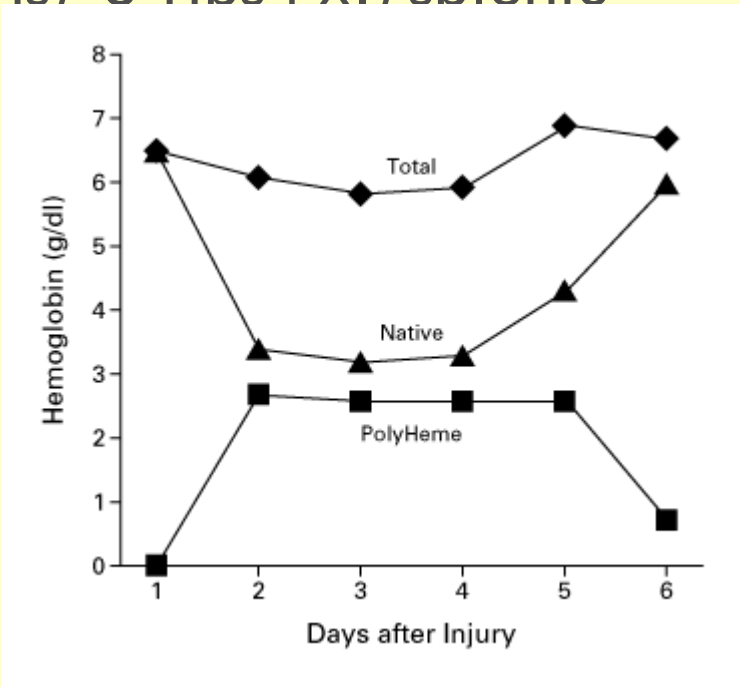
subarachnoid hemorrhage/orbital tripod fracture/ bilateral pulmonary contusions/ 3-ribs Fx./splenic laceration

hemodynamically stable,

Hb 11 g/dL → 5.4 g/dL

the family & church elders

Agree on EPO & PolyHeme



PolyHeme 5 unit

EPO

600 unit/kg 24 & 48 hr after the injury

300 unit/kg on 3rd, 4th, & 5th day

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Preoperative Autologous Donation (PAD)

DRAWBACKS

PAD programs are not without some drawbacks. Perhaps the most important is that autologous blood is considerably more expensive than allogeneic blood. This problem is compounded by the fact that current reimbursement programs (including Medicare) either deny the medical necessity of PAD or ignore the well-documented increase in cost

The basis for the higher cost include the extra time & attention required by autologous donor/patients; the enhanced clerical requirements; the special handling (additional labels, separate storage, early delivery to the hospital, etc); & the fact that blood that is not transfused to the intended recipient (approximately 50 % of donated blood) is generally wasted rather than transfused to other patients

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Acute Normovolemic Hemodilution (ANH)

Intraoperative, removal immediately before or shortly after induction of anesthesia

Hb to 5 g/dL (= Hct about 15 %)

or 1-3 units (450-500 mL /unit),

larger volumes in certain circumstances

isovolemia by crystalloid / colloid replacement.

no evidence of inadequate O2 delivery,

since ↓in Hb progressive ↑in SV & HR (cardiac output)

a progressive ↓ in SVR.

HR was found to increase linearly in response to the acute isovolemic anemia,

HR (beats/min) = 116 - 4.0 x Hgb (g/dL)

(*Transfusion 2003; 43:235*)

Storage at room temperature, in the OR, for up to 8 hours

Used as the sole technique or combined w PAD & IC

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Acute Normovolemic Hemodilution (ANH)

ANH with albumin administration to Hb to 5g/dL at rest in supine position, O2 delivery to tissues was maintained

(JAMA 1998;279:217-21)

Vigorous combination of EPO, aprotinin, ICS, & ANH resulted in only a 4% mortality, none due to anemia

Hct at the time of hospital discharge were somewhat higher than in a control group of pts who received allogeneic transfusions

(J Am Coll Sur **184**,618-629)

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Intraoperative Cell Salvage (ICS)

= intraoperative autologous transfusion,
= intraoperative salvage,
= intraoperative autotransfusion

Modern cell salvage instruments

- 225 mL of washed, saline-suspended RBC
- Hct > 50 % or more in approximately 3 min
- a massively bleeding = the equivalent of 12 unit/hour of banked blood per hour

Aprotinin?

Perhaps the most promising drug to come along in the last decade to reduce surgical blood loss is aprotinin, a naturally occurring serine protease inhibitor that probably affects hemostasis through several mechanisms: it is antifibrinolytic, inhibits kallikrein, inhibits plasmin & activated protein C, & possibly preserves platelet function.

A number of controlled randomized studies support its use to reduce surgical blood loss in cardiac surgery, w/o compromising graft patency

Anti-fibrinolytics

Lysine Analogs,

Epsilon Amino Caproic Acid (EACA)

Tranexamic Acid

inhibit plasminogen & plasmin binding to fibrin

While not shown to be helpful once active pathologic bleeding is manifest, when used prophylactically, they do reduce blood loss

Urinastatin

Hb Solutions

pyridoxilated polymerized stroma-free Hb (Poly SFH-P)

short half-life in circulation (about 8 h for ultra-purified polymerized bovine Hb)

ANH with poly SFH

instead of crystalloid or colloid

Hemopure™

a highly purified O2-carrying Hb solution

made from fractionated bovine blood

Cryoprecipitate

Ix
- fibrinogen deficiency in the setting of hemorrhage
- invasive procedures & injury
- acute DIC

Fibrinogen levels
- < 100 mg/dL
- or 150 mg/dL in patients with active hemorrhage
- generally transfused in aliquots of 10 units

Pts receiving > 10 units of FFP generally do not need additional cryoprecipitate

Recombinant activated factor VII (rFVIIa)

synthesized human factor VII that is available for reconstitution & infusion in patients with massive hemorrhage. rFVIIa has typically been used to treat hemophilia and other congenital and acquired coagulopathies. More recently, rFVIIa has been used in pts with active hemorrhage & coagulopathy from trauma, traumatic brain injury, excessive warfarin use, & other acquired hematologic defects, including acquired factor inhibitors

Intraoperative Transfusion Triggers in Konkuk Cardiac Anesthesia

- Hb
- SvO_2 (or $ScvO_2$)
- Lactate
- Regional cerebral O_2 saturation
- Hemodynamic parameters
- Coagulation profile (TEG, ROTEM™)

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Konkuk Strategy for JW's Cardiac Surgery

EPO 1000 unit
ANH > 2-3 unit in CPD bags
Synthetic colloids > crystalloid
aggressive ICS, for CPB or postoperative use
Volume titration to avoid severe hemodilution
TEE
Meticulous monitoring for SvO2, Cerebral O2
Frequent ABGA for lactate, osmolarity, Elctrolyte, Hct
Albumin
Mannitol
ROTEM
Cryoprecipitate
Ulistin & Tranexamic acid

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Konkuk CPB regimen

CPB priming volume (adult cardiac surgery)

- Nomal saline 1000 ml
- 20% mannitol 100 ml x 2
- 20% albumin 100 ml
- NaHCO3(Bivon) 8.4% 60 ml
- Heparin 5000 unit 5ml
- antibiotics 15 ml

Total priming volume 1380 ml

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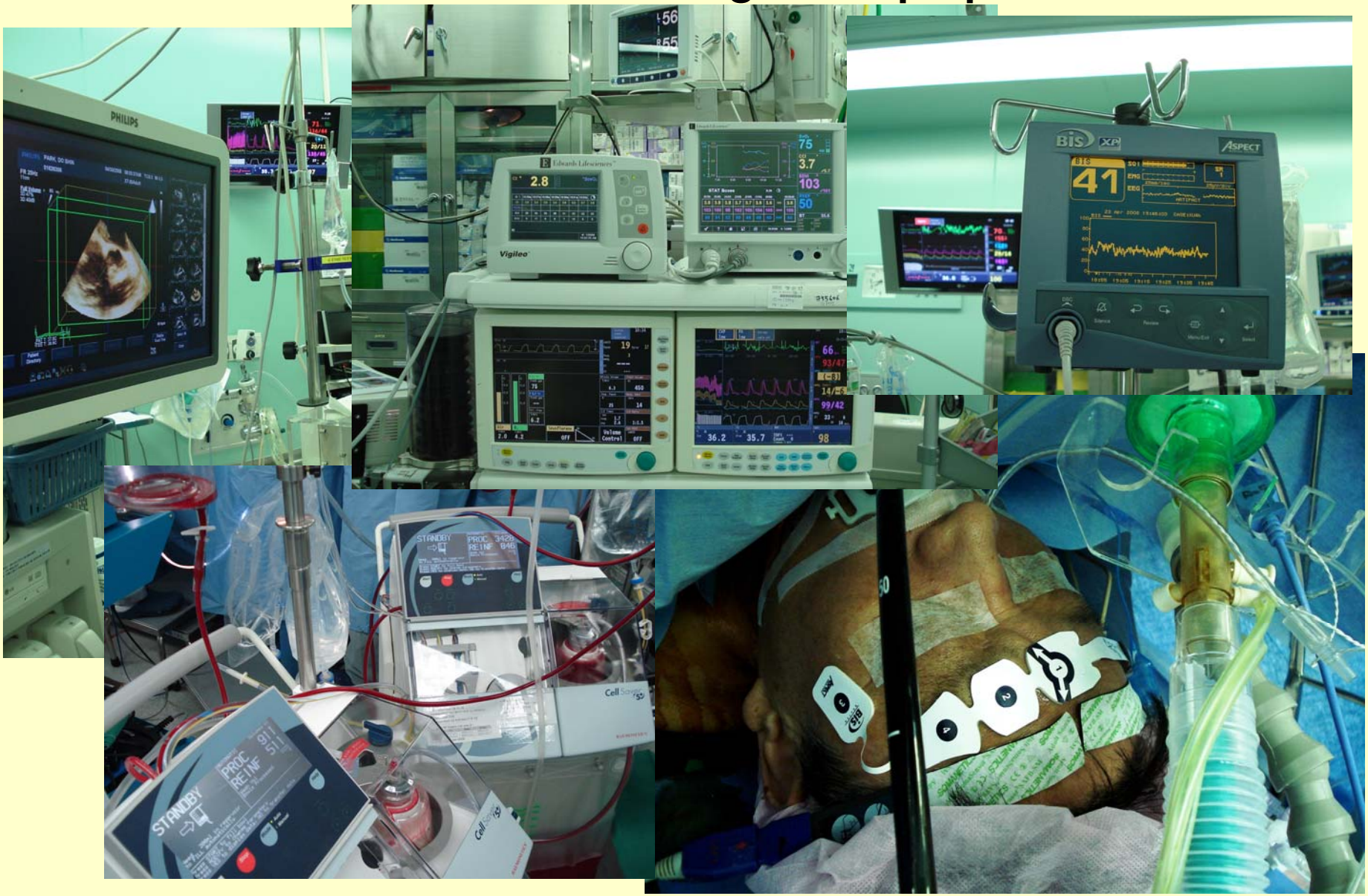
Konkuk Intraoperative Monitoring

Pulse Ox
Bispectral index
ECG
Cerebral Ox.
2 arterial lines (central/peripheral)
  Art. pressure waveform-CO monitor (FloTrac™), SVV
2 central venous lines
  AVA™ (9 Fr)
    rapid infusion system
    PA catheter for continuous CO (SvO2)
  3-lumen CVC for medication
TEE (2D & 3D)
Thromboelastography or thromboelastometery(ROTEM™)

Konkuk Monitoring & Equipment

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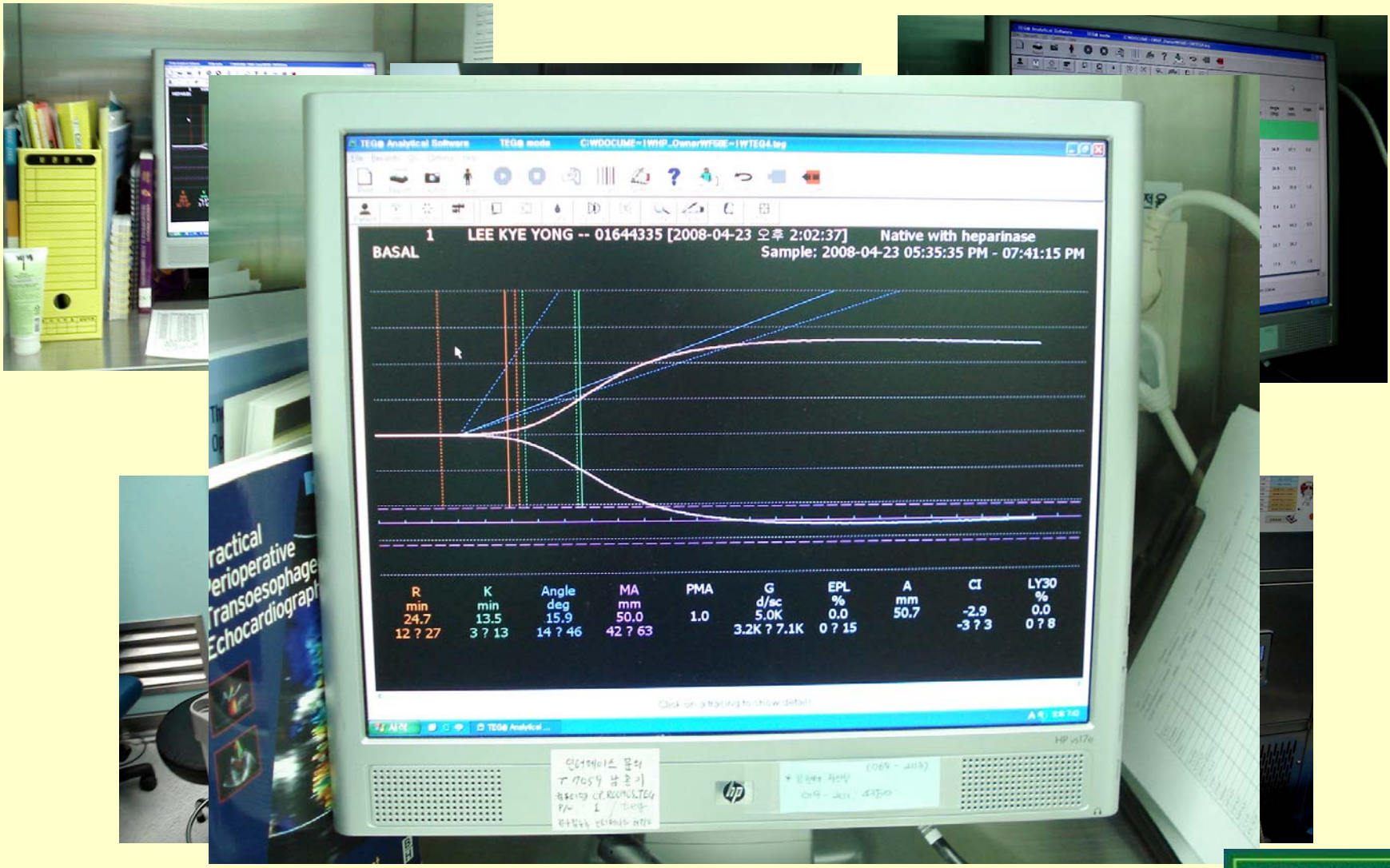
Thromboelastography (TEG) & ROTEM™



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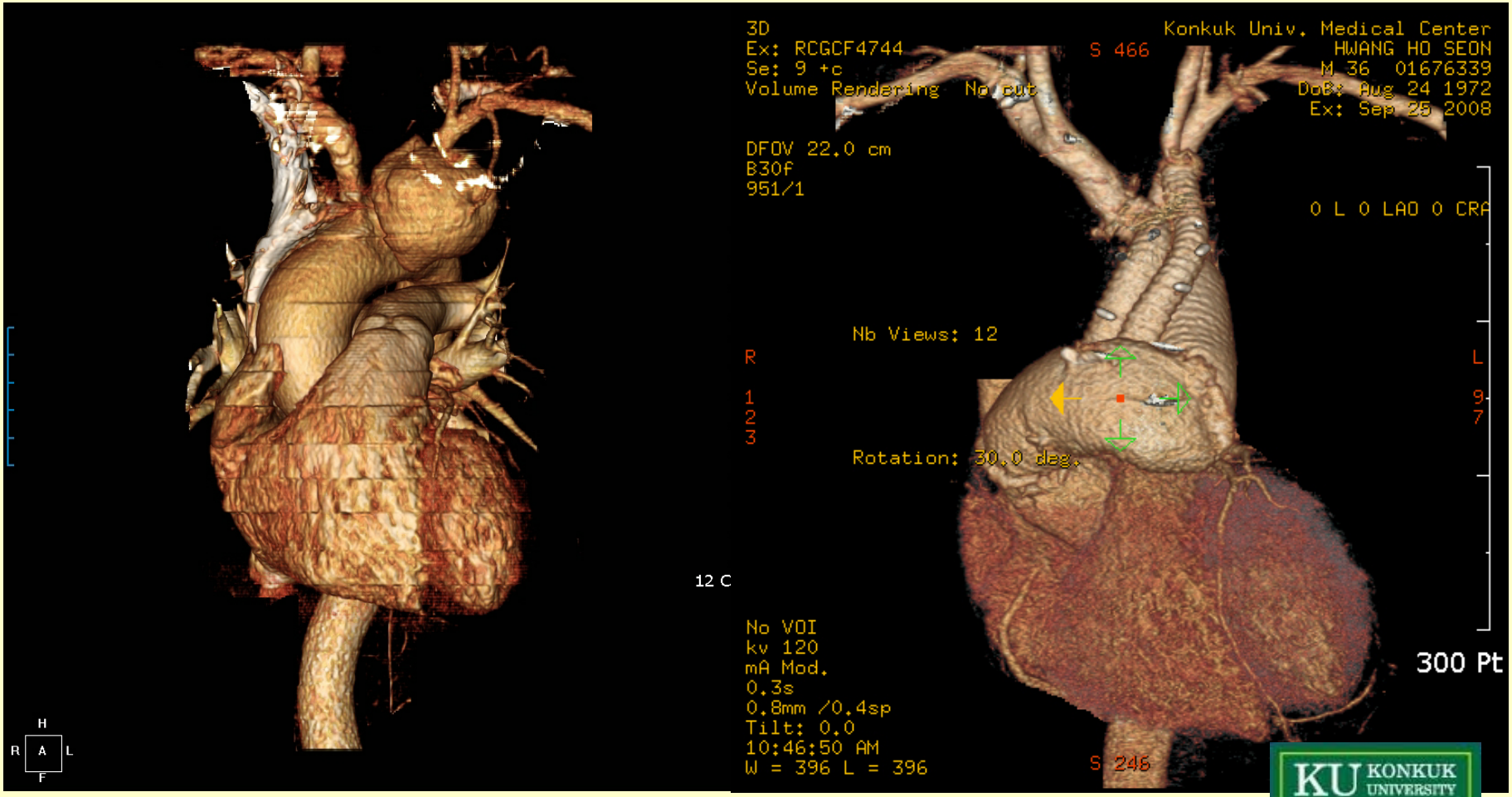
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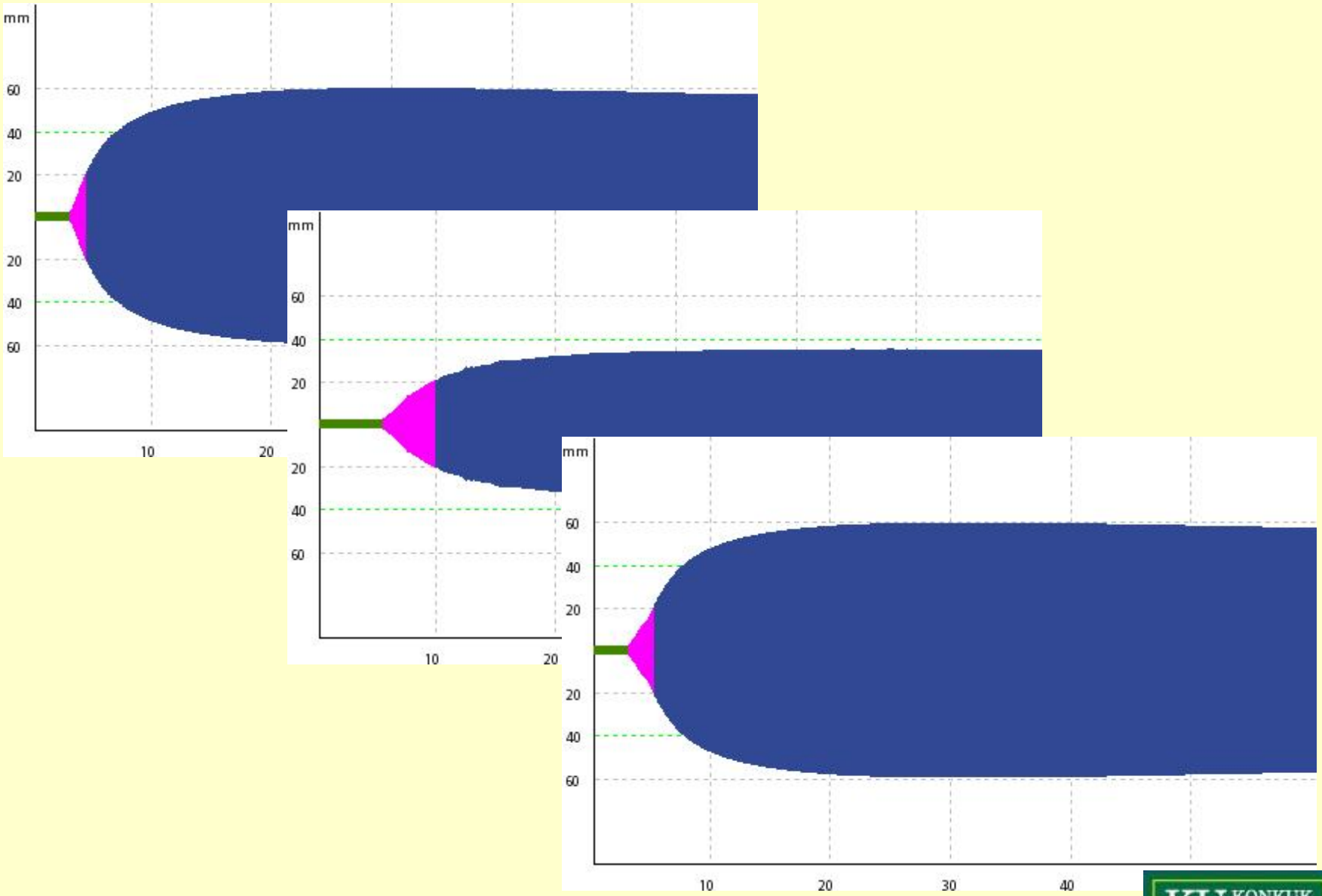
Hct 32%
albumin 3.2 g/dl
platelet 270K/mm³

EPO 42K u

ANH 1.5 L
ICS 0.8/2.8 L
Voluven 2.5 L
Plasmasol™ 1.5 L
20-albunin 0.2 L
20-mannitol 0.1 L

UO 1.5 L

	peop	preCPB			CPB			Post-CPB			postop			
		1	2	3	1	2	3	1	2	3	1 D	2 D	3D	4 D
Hct (%)	32	35	32	33	22	17	18	20	23	25	26	25	23	31
Albumin	3.0										2.3	2.9	2.8	3.8
Urine						1.5L								
ANH			1.5L											
S.Blood							540			960				
ICS				0.8					2.8					
P.S						1.5L								
Voluven			1L											
$PaCO_2$	29.4	33	31	33	34	30	32	33	32	37	29.8	31.0	31.2	
PaO_2	94.7	247	238	262	313	383	290	279	265	246	196.8	144.6	121.9	
HCO_3	22.5	21.1	23.6	34.6	24.6	25.1	21.0	27.4	25.1	26.0	21.7	22.2	23.3	
BE	0.5	1.5	1.4	2.0	1.06	2.8	-2.5	5.0	2.6	2.5	-0.8	-0.6	0.7	
FiO_2		0.6	0.5	0.5				0.6	0.6	0.6	0.35	0.3	0.3	
Na	136.5	139	138	136	134	135	134	141	142	143	140.6	135.3	133.6	
K	4.8	3.46	3.43	3.76	2.88	5.21	1.08	1.30	1.13	1.09	4.11	4.01	3.93	
Ca	0.96	1.17	1.14	1.18	1.05	1.39	1.08	1.30	1.13	1.09	1.02	1.11	1.11	
SvO2		78	74	70				67	68	64				
CbO2-L		59	55	58	51	65	71	46	51	50				
CbO2-R		63	59	55	57	65	70	48	49	47				
Osmolarity		277	276	273	274	274		285	285	286				
BUN		8	8	9	8	9	1	9	8	8				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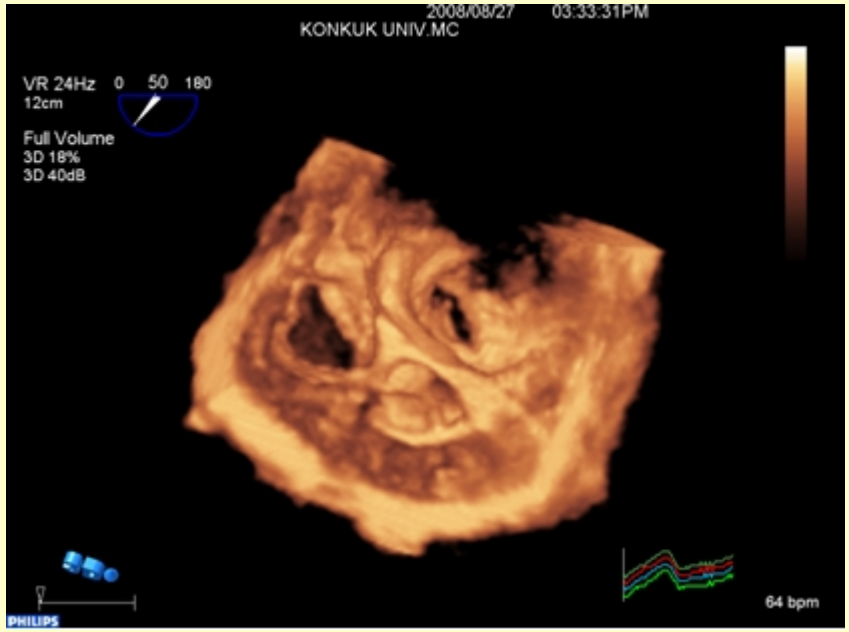

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