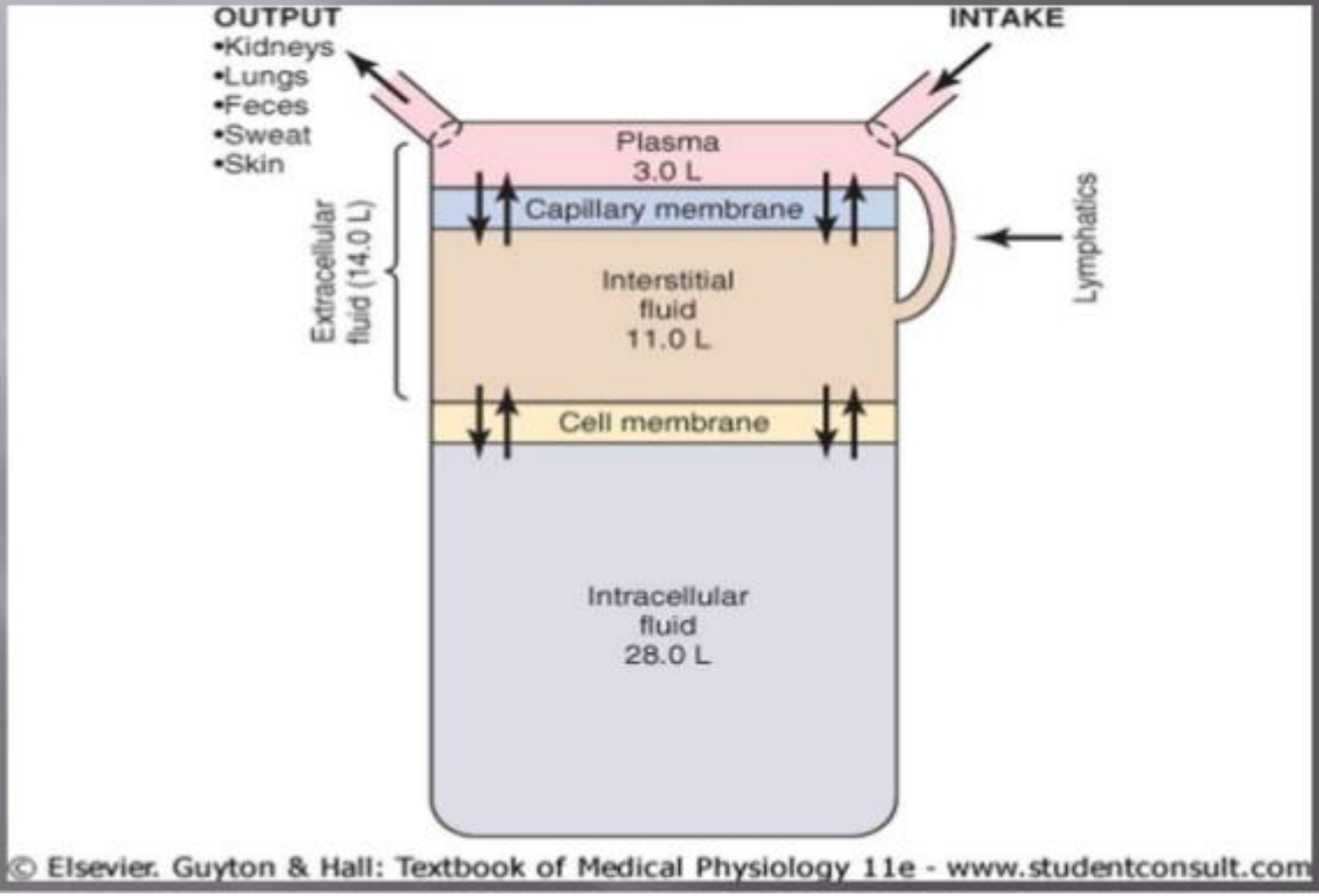
FLUID & ELECTROLYTES

COL.TEERAWAT POOJINYA

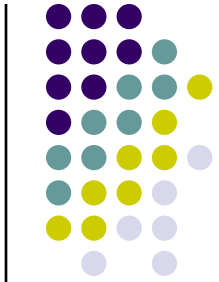
Total body fluid

- Intracellular fluid
- Extracellular fluid
  - Interstitial fluid
  - Intravascular fluid

Body fluid compartments



Fluid Replacement(Holliday sugar)



- Maintenance
  - 0-10 kg = 4cc/kg/hr
  - 10-20kg = 2 cc/kg/hr
  - 20 kg = 1cc/kg/hr
- Deficit
  - NPO time* maintenance
- Loss
  - Thirdspace loss
  - Blood loss

Maintenance fluid solution

- Adult daily sodium requirement = 75 mEq
- Adult daily potassium requirement = 40 mEq
- Dextrose solution ; indicated → neonate, infant, patient on insulin therapy
- Most intraoperative fluid losses → isotonic!
- The most commonly used fluid → LRS !

Replacing blood loss

- Blood loss → crystalloid or colloid solutions
- & → to maintain intravascular volume
- & → normovolemia
- Crystalloid→3-4 : 1(Holliday Segar)
- Colloid → 1:1
- Transfusion point → packed red cells IV

ในปัจจุบันเราจะนิยมใช้เป็น

Goal directed fluid therapy

Too much, too little or just right?

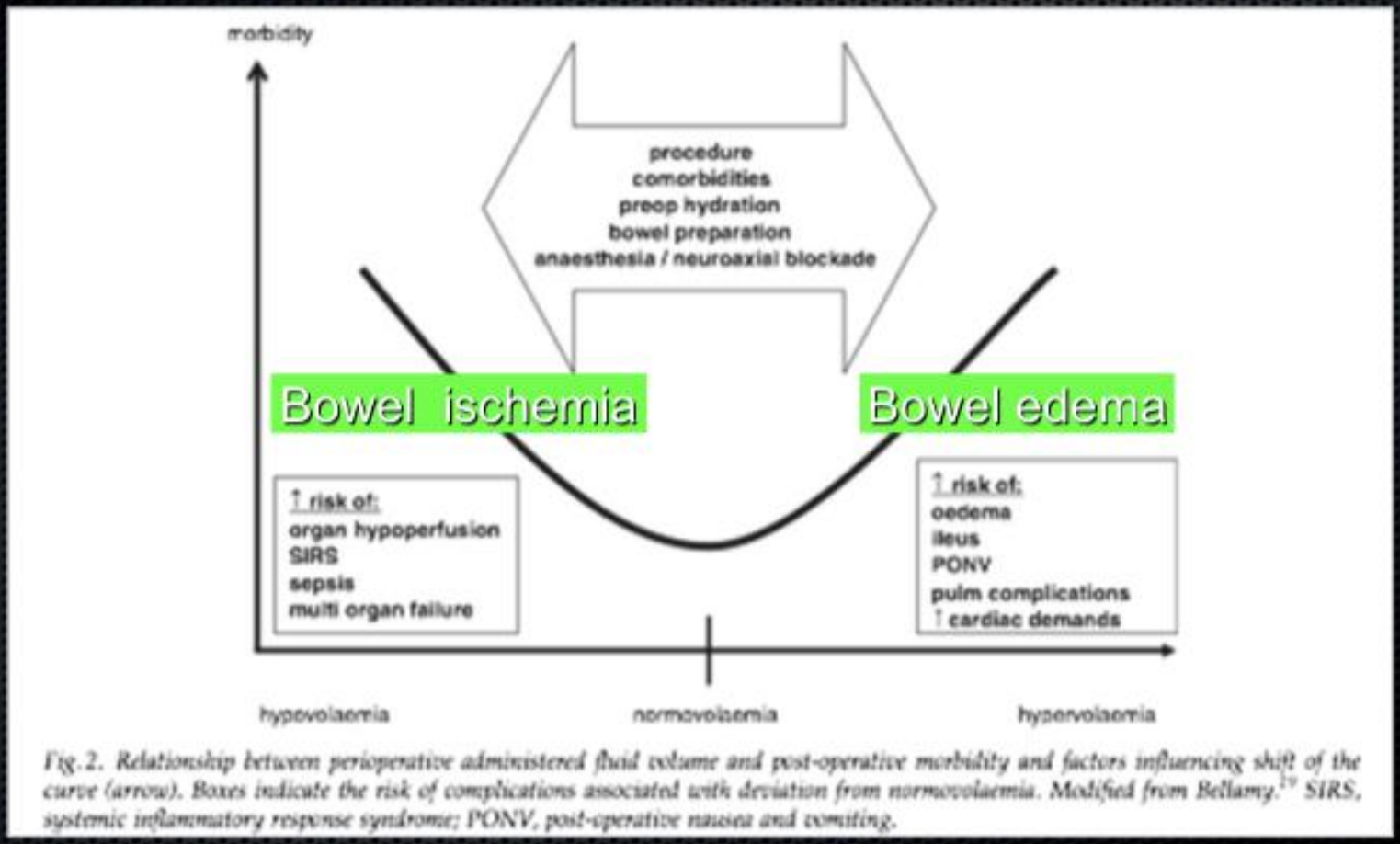


Fig. 2. Relationship between perioperative administered fluid volume and post-operative morbidity and factors influencing shift of the curve (arrow). Boxes indicate the risk of complications associated with deviation from normovolaemia. Modified from Bellamy.[19] SIRS, systemic inflammatory response syndrome; PONV, post-operative nausea and vomiting.

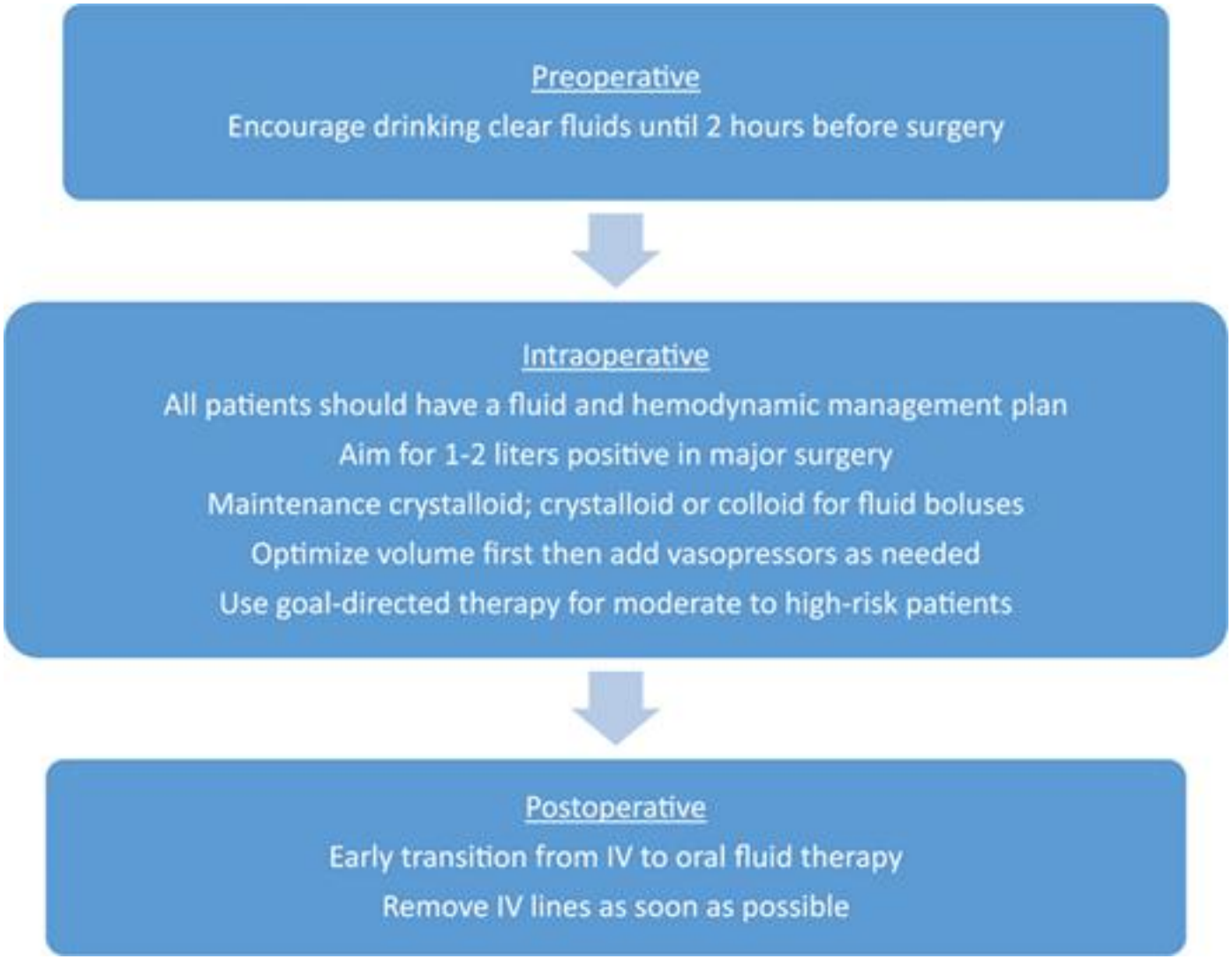
Bundgaard-Neilsen M et al. Acta Anaesthesiol Scand 2009;53:843

Goal directed fluid therapy

1. Minimize preoperative fasting times. Encourage unrestricted intake of clear fluids until 2 h before elective surgery.[13,14]
2. Passive leg raising followed by measurement of blood pressure or (ideally) stroke volume is a useful test for predicting fluid responsiveness in hemodynamically unstable adults throughout the perioperative period.[20]
3. Aim for a moderately liberal IV fluid regimen with an overall positive fluid balance of 1–2 l at the end of surgery.[30] For major abdominal surgery, an average crystalloid fluid infusion rate of 10–12 ml · kg^{-1} · h^{-1} during surgery, and 1.5 ml · kg^{-1} · h^{-1} in the 24-h postoperative period should be used.
4. Ensure that intravascular volume status is optimized before adding vasopressor therapy.
5. Use an advanced hemodynamic monitor to measure fluid responsiveness in higher-risk patients having major surgery.
6. A goal-directed hemodynamic strategy may perform better if a patient's IV fluid status is first optimized, and if needed, introduce a vasopressor or inotrope.[37,38]
7. It is unclear whether crystalloid or colloid should be primarily used for perioperative fluid resuscitation.
8. Aim for early transition from IV to oral fluid therapy after surgery (usually within 24 h).[1,2]

IV, intravenous.

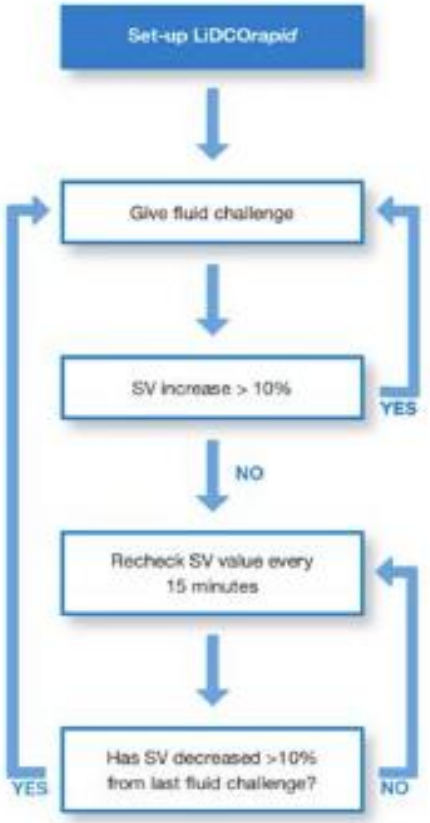
Timothy E. Miller, Paul S. Myles; Perioperative Fluid Therapy for Major Surgery. *Anesthesiology* 20


Preoperative
Encourage drinking clear fluids until 2 hours before surgery
Intraoperative
All patients should have a fluid and hemodynamic management plan
Aim for 1-2 liters positive in major surgery
Maintenance crystalloid; crystalloid or colloid for fluid boluses
Optimize volume first then add vasopressors as needed
Use goal-directed therapy for moderate to high-risk patients
Postoperative
Early transition from IV to oral fluid therapy
Remove IV lines as soon as possible

LiDCO Cardiac Sensor Systems

LiDCO Rapid

Example of Intra & post operative optimisation guidance



MAINTAIN:

SaO2 > 94%, Hb 8-10 g/dL, Temp 37°C, MAP 60-100 mmHg

Adult Fluid Challenge Guidelines:

Administer a 250ml fluid bolus (colloid or crystalloid) < 5 mins.

1. Use wide bore cannula if available.
2. Give rapidly with 50ml syringe and 3 – way tap (a pressure bag is an alternative).

Starting SV .....

SV Max .....

Total intra-operative fluid volume:

.....mls

GDT

"The volume of Lactated Ringer's solution required to maintain preload and cardiac index during open and laparoscopic surgery"

OPEN : ~ **6 ml/kg/hr**

LAPAROSCOPIC: ~ **3.5 ml/kg/hr**

(Concha, Anesth Analg 2009;108:616-21)

Transfusion point

- Hematocrit = 21 – 24 %
- 30% → elderly, cardiac, pulmonary disease
- Estimated allowable blood loss (EABL)
- $EABL = \frac{Hct\ starting - Hct\ allowable \times BV}{Hct\ starting + Hct\ allowable\ /\ 2}$

Serial hematocrit

Blood volume(BV) ; M=75/F=65 mL/kg

ตารางที่ 3 ความสัมพันธ์ของอุณหภูมิกาย ชีพจร และร้อยละการสูญเสียสารน้ำของร่างกาย

ร้อยละของการสูญเสียสารน้ำ		อุณหภูมิ	ชีพจร
เด็ก	ผู้ใหญ่		
5	3	มือ/เท้า เย็น	คลำ radial/dorsalis pedis ยาก
10	6	น่อง/แขนต่ำกว่าศอกเย็น	คลำ brachial/popliteal ยาก
15	9	แขน/ขา ทั้งหมดเย็น	คลำชีพจรแทบไม่ได้

ตารางที่ 4 ค่าการตรวจทางห้องปฏิบัติการที่บอกถึงภาวะขาดสารน้ำ

การตรวจทางห้องปฏิบัติการ	ค่าที่ได้
การตรวจฮีมาโตคริตซ้ำ ๆ	เพิ่มขึ้น
ความเป็นกรดของเลือด	เพิ่มขึ้น
ความถ่วงจำเพาะของปัสสาวะ	> 1.010
ปริมาณโซเดียมในปัสสาวะ	< 10 mEqต่อลิตร
ความเข้มข้นของปัสสาวะ	> 450 mOsmต่อกก.
ปริมาณโซเดียมในเลือด	เพิ่มขึ้น
BUN/Cr	> 10:1

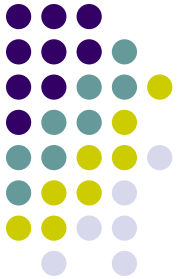
ในการให้สารน้ำโดยอาศัยค่า CVP

หาก CVP สูงขึ้นจากเดิมมากกว่า

FLUID

- CRYSTALLOID
  - ISOTONIC
  - HYPOTONIC
  - HYPERTONIC
- COLLOID
  - Colloid ตามธรรมชาติ
  - Colloid สังเคราะห์

Crystalloid solutions



- Normal saline, balanced salt solutions ; lactated Ringer's and acetated Ringer's
- Intravascular half-life of isotonic crystalloid solutions = 20-30 minutes
- Most intraoperative fluid losses → isotonic
- The most commonly used fluid → lactated Ringer's solution

Crystalloids …

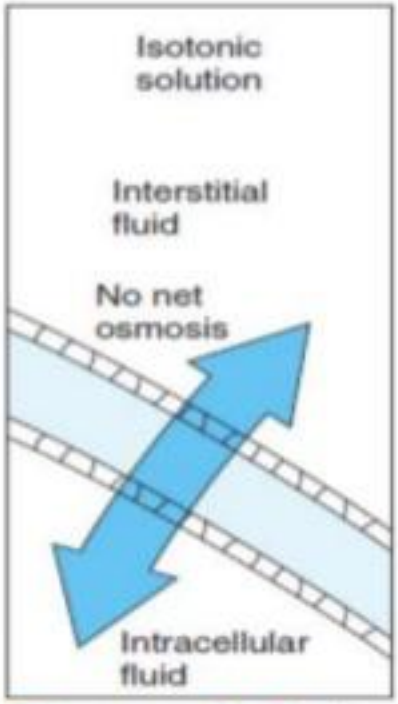


Figure 3-2. Isotonic solutions do not result in any significant fluid shifts across cellular or vascular membranes.

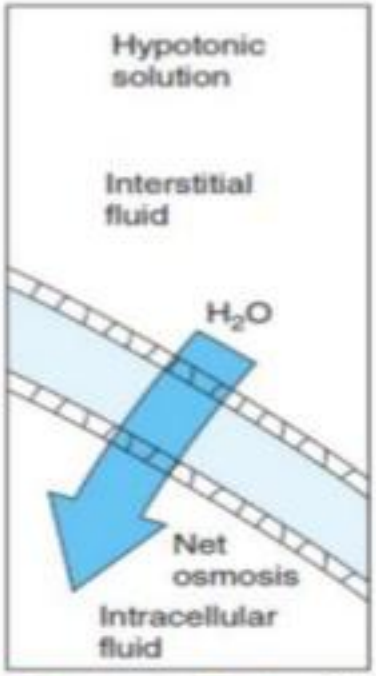


Figure 3-4. A hypotonic solution given IV will cause fluids to leave the vasculature for the interstitial and intracellular spaces.

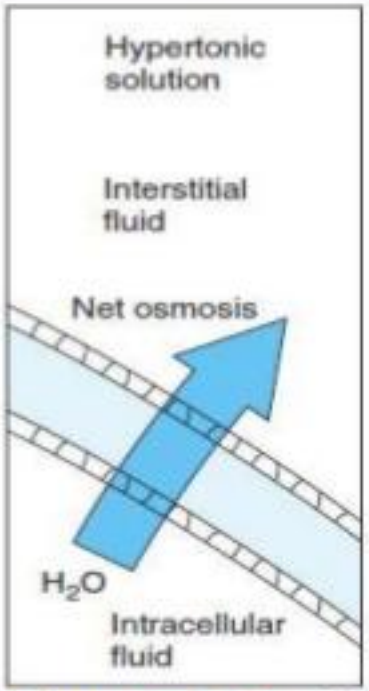


Figure 3-3. A hypertonic solution given IV will draw fluids from the cells and interstitial spaces into the vasculature.

Isotonic saline(0.9 % NS)

- *Composition* : Na 154 mEq, Cl 154 meq
- *Pharmacological basis* : provide major EC electrolytes.. corrects both water and electrolyte deficit. increase the iv volume substantially

Contra indications

- Avoid in pre eclamptic patients, CHF, renal disease and cirrhosis
- Dehydration with severe hypokalemia – deficit of IC potassium
- Large volume may lead to hyperchloremic acidosis.

Indications

- Water and salt depletion – diarrhoea, vomiting, excessive diuresis
- Hypovolemic shock
- Alkalosis with dehydration
- Severe salt depletion and hyponatremia
- Initial fluid therapy in DKA
- Hypercalcemia
- Fluid challenge in prerenal ARF
- Irrigation – washing of body fluids
- Vehicle for certain drugs

Ringer's lactate

Composition – Na, k , cl, lactate , ca

each 100 ml – sodium lactate 320 mg, Nacl -600mg, kcl-40mg, calcium chloride 27 mg

Pharmacological basis :

- Most physiological fluid , rapidly expand s iv volume..
- Lactate metabolised in liver to bicarbonate providing buffering capacity
- Acetate instead of lactate advantageous in severe shock.

Indications

- Correction in severe hypovolemia
- Replacing fluid in post op patients, burns
- Diarrhoea induced hypokalemic metabolic acidosis
- Fluid of choice in diarrhoea induced dehydration in paediatrics
- DKA , provides water, correct metabolic acidosis and supplies potassium
- Maintaining normal ECF fluid and electrolyte balance

Composition of commonly used intravenous fluids: Crystalloids

Intravenous fluids	MOsm/l[a]	mEq/l					g/l	
		Na^+	Cl^-	K	Ca	Mg	Lactate	Dextrose (g/l)
5% Dextrose in water (D5W)	278							50
5% Dextrose in 0.45% NaCl	405	77	77					50
5% Dextrose in 0.9% NaCl	561	154	154					50
5% Dextrose in Ringer's solution	525	130	109	4	3			50
Ringer's solution	309	147	156	4	4–4.5			
Lactated Ringer's solution	275	130	109	4	3		28	
5% Dextrose in Lactated Ringer's solution	525	130	109	4	3		28	50
Plasmalyte[b]	298	140	98	5		3		
0.45% NaCl	154	77	77					
0.9% NaCl	308	154	154					
3.0% Saline	1026	513	513					
5.0% Saline	1710	855	855					
7.5% Saline	2566	1283	1283					
20% Mannitol	1098							

COLLOID

แบ่งตามแหล่งกำเนิดออกเป็น 2 ชนิด ได้แก่

- Colloid ตามธรรมชาติ
  - Plasma protein solution
  - 5% & 25% Albumin
- Colloid สังเคราะห์
  - Dextran
  - Gelatin
  - Hydroxyethyl starch (HES)

5% & 25% Albumin

- นิยมใช้ในรูป 5%&25%, Half life 15 วัน
- ข้อบ่งใช้
  - ทดแทนโปรตีนในผู้ป่วยที่สูญเสียโปรตีนทางพลาสมา เช่น ไฟไหม้/น้ำร้อนลวก
  - ใช้เพิ่มความดัน Osmotic
- ข้อควรระวัง ความดันเลือดต่ำจากหลอดเลือดขยาย


Albumin (Human), USP, 5% Solution
Buminate® 5%
5%

Dextran

- นิยมใช้ในรูป 6%&10%, Half life 4 ชั่วโมง
- ปริมาณไม่เกิน 1.5 กรัม/กก./วัน
- ข้อบ่งใช้
  - ลดความหนืดของเลือด
  - ใช้เพิ่ม Circulatory volume
  - มีฤทธิ์ Antithrombotic
- ข้อควรระวัง Anaphylactoid, Volume overload, ไตวาย, บาดแผลมีเลือดออกไม่หยุด


DEXTRAN 40
INJECTION
B.P.

Gelatin

- นิยมใช้ 3 ชนิด
  - Oxypolygelatin ; 3% Gelifundol
  - MFG ; Gelofusine
  - Polygeline ; Haemaccel, Half life 2-4 ชั่วโมง
- ข้อบ่งใช้
  - ใช้เพิ่ม Circulatory volume
  - ใช้ทำ Hemodilution, Plasma exchange & Hemodialysis
- ข้อควรระวัง Anaphylactoid

HAEMACCEL®

Globally most accepted colloid

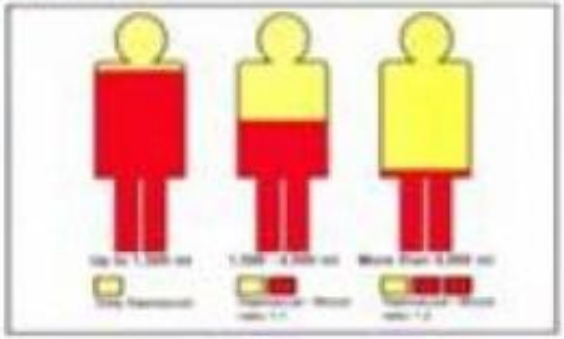
Whenever blood is lost...

HAEMACCEL® stabilizes the patient, prevents shock and saves lives. HAEMACCEL® is a 3.5% iso-oncotic polygeline solution.

HAEMACCEL major indications:

- Blood and Plasma loss
- Dehydration
- Hypovolemic Shock
- Volume loss during and after Surgery
- Pre-operative hemodilution

Principles of replacement of blood loss with Haemaccel:



Hydroxyethyl starch (HES)

- ทำจากข้าวโพดและถั่วเหลือง, Half life 6 ชั่วโมง
- ข้อบ่งใช้
  - ใช้เพิ่ม Circulatory volume
- ข้อควรระวัง Anaphylactoid, False positive agglutination,AKI


freeflex
500 mL
Voluven

Table 2

Composition of commonly used intravenous fluids: Colloids

Intravenous fluids	mEq/l				Osmolarity[a] (mOsm/l)	Oncotic pressure (mm Hg)
	Na^+	Cl^-	K	Ca		
Fresh-frozen plasma	168	76	3.2	8.2	≈ 300	21
5% Albumin					290	19
Dextran (10%) 40 in 0.9% saline	154	154			≈ 310	61
Dextran (6%) 70 in 0.9% saline	154	154			≈ 310	19
Hetastarch (6%) in 0.9% saline	154	154				31
Hetastarch (10%) in 0.9% saline	154	154			≈ 310	82

Electrolyte Composition in Body Fluids

	PLASMA	INTRACELLULAR	EXTRACELLULAR
	(mEq/L)	FLUID (mEq/L)	FLUID (mEq/L)
Sodium	142	10	140
Potassium	4	150	4.5
Magnesium	2	40	2
Calcium	5	1	5
Chloride	103	103	117
Bicarbonate	25	7	28

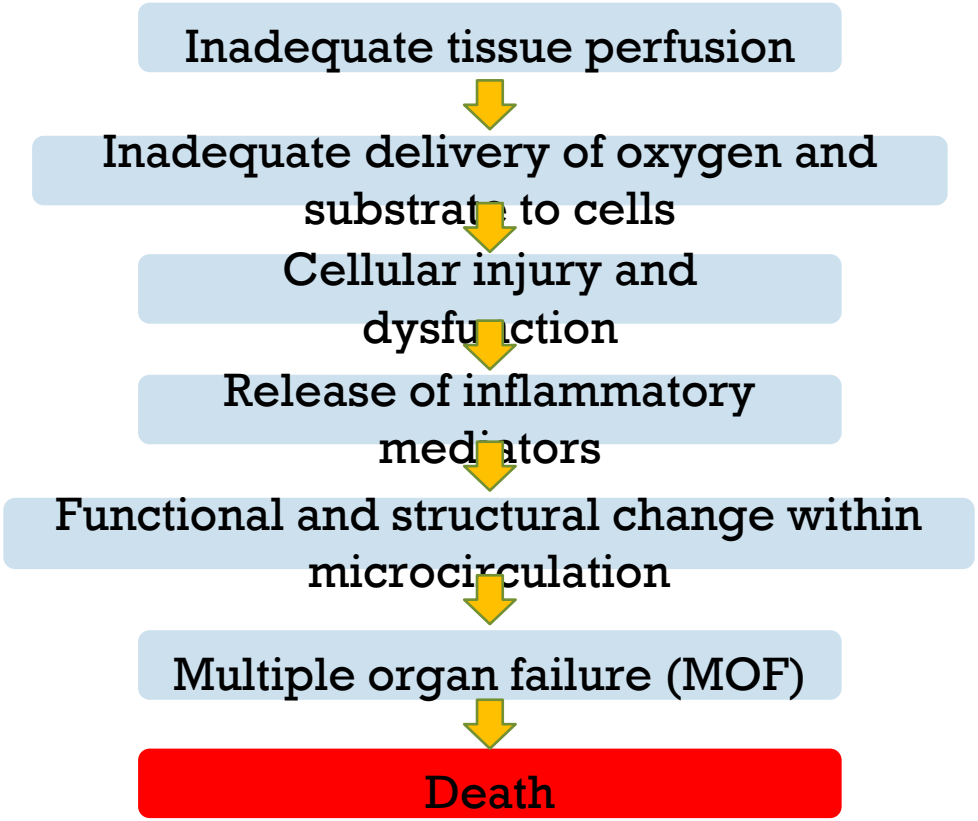
Definition

- Shock
  - State of cellular and tissue hypoxia
    - Reduced oxygen delivery
    - And/or increased oxygen consumption
    - Inadequate oxygen utilization

Physiology

- *BP = cardiac output (CO) x systemic vascular resistance (SVR)*
  - *CO = stroke Volume (SV) x heart rate (HR)*
- *BP = SV x HR x SVR*
  - *SV = end diastolic volume (EDV) – end systolic volume (ESV)*
- *BP = (EDV – ESV) x HR x SVR*
  - *BP = EDV x (EDV-ESV)/ EDV x HR x SVR*
  - *ejection fraction (EF) = (EDV-ESV)/EDV*
- *BP = EDV x EF x HR x SVR*
- **Blood pressure = preload x contraction x heart rate x afterload**

PATHOPHYSIOLOGY



CLASSIFICATION

TABLE 12-4 Categories of Shock

Type	Hemodynamic Changes	Etiologies
Hypovolemic	Decreased preload, increased SVR, decreased CO	Hemorrhage, capillary leak, GI losses, burns
Cardiogenic	Increased preload, increased afterload, increased SVR, decreased CO	MI, dysrhythmias, heart failure, valvular disease
Obstructive	Decreased preload, increased SVR, decreased CO	PE, pericardial tamponade, tension PTX
Distributive	Decreased preload, increased SVR, mixed CO	Sepsis, neurogenic shock, anaphylaxis

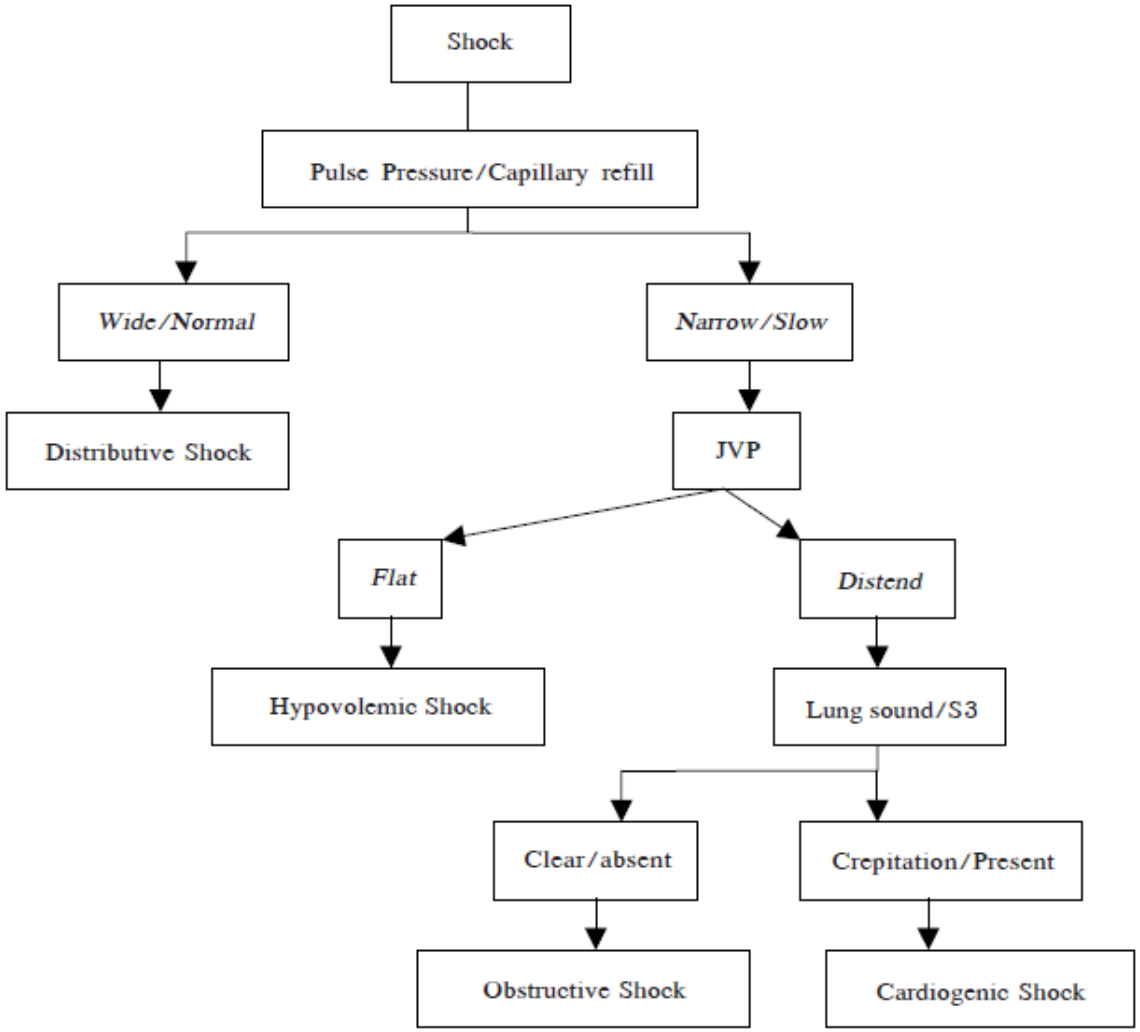
Abbreviations: CO = cardiac output; MI = myocardial infarction; PE = pulmonary embolism; PTX = pneumothorax; SVR = systemic vascular resistance.

Classification of shock

Distributive	**Septic**	▪ Gram positive (*Pneumococcus, Staphylococcus, Streptococcus, Enterococcus, Legionella, Listeria*) ▪ Gram negative (*Klebsiella, Pseudomonas, Escherichia, Haemophilus, Neisseria, Moraxella, Rickettsia, Francisella* [*tularemia*]) ▪ Fungal (*Candida, Aspergillus*) ▪ Viral (influenza, cytomegalovirus, Ebola, varicella) ▪ Parasitic (*Plasmodium, Ascaris, Babesia*) ▪ Mycobacterium (*Mycobacterium tuberculosis, Mycobacterium abscessus*)
	Non-septic	▪ Inflammatory shock (systemic inflammatory response syndrome) – burns, trauma, pancreatitis, postmyocardial infarction, post coronary bypass, post cardiac arrest, viscus perforation, amniotic fluid embolism, air embolism, fat embolism, idiopathic systemic capillary leak syndrome ▪ Neurogenic shock – traumatic brain injury, spinal cord injury, mitochondrial dysfunction ▪ Anaphylactic shock – bee stings, food and drug allergies ▪ Drugs and toxins – vasodilatory agents (eg, overdose narcotics), insect bites, transfusion reactions, heavy metal poisoning, toxic shock syndrome, carbon monoxide and cyanide poisoning. ▪ Endocrine shock – adrenal crisis, myxedema coma

Cardiogenic	**Cardiomyopathic**	▪ Myocardial infarction (involving >40% of the left ventricle or with extensive ischemia) ▪ Severe right ventricle infarction ▪ Acute exacerbation of severe heart failure from dilated cardiomyopathy ▪ Stunned myocardium from prolonged ischemia (eg, cardiac arrest, hypotension, cardiopulmonary bypass) ▪ Advanced septic shock ▪ Myocarditis
	Arrhythmogenic	▪ Tachyarrhythmia – atrial tachycardias (fibrillation, flutter, reentrant tachycardia), ventricular tachycardia and fibrillation ▪ Bradyarrhythmia – complete heart block, Mobitz type II second degree heart block
	Mechanical	▪ Severe aortic or mitral valve insufficiency, acute valvular rupture (papillary or chordae tendineae rupture, valvular abscess), critical aortic stenosis, acute or severe ventricular septal wall defect, ruptured ventricular wall aneurysm, atrial myxoma

Hypovolemic	**Hemorrhagic**	▪ Trauma, gastrointestinal bleeding (eg, varices, peptic ulcer), intraoperative and postoperative bleeding, ruptured aortic or left ventricle aneurysm, aortic-enteric fistula, hemorrhagic pancreatitis, iatrogenic (eg, inadvertent biopsy of arteriovenous malformation, or left ventricle), tumors or abscess erosion into major vessels, postpartum hemorrhage, uterine or vaginal hemorrhage (eg, infection, tumors, lacerations), spontaneous peritoneal hemorrhage from bleeding diathesis
	Non-hemorrhagic	▪ Gastrointestinal losses (eg, diarrhea, vomiting, external drainage); skin losses (eg, heat stroke, burns, dermatologic conditions); renal losses, (eg, excessive drug-induced or osmotic diuresis, salt-wasting nephropathies, hypoaldosteronism); third space losses into the extravascular space or body cavities (eg, postoperative and trauma, intestinal obstruction, crush injury, pancreatitis, cirrhosis)
Obstructive	**Pulmonary vascular**	▪ Hemodynamically significant pulmonary embolus, severe pulmonary hypertension, severe or acute obstruction of the pulmonic or tricuspid valve
	Mechanical	▪ Tension pneumothorax (trauma, iatrogenic, ventilator-induced), pericardial tamponade, constrictive pericarditis, restrictive cardiomyopathy


Shock
Pulse Pressure/Capillary refill
Wide/Normal
Narrow/Slow
Distributive Shock
JVP
Flat
Distend
Hypovolemic Shock
Lung sound/S3
Clear/absent
Crepitation/Present
Obstructive Shock
Cardiogenic Shock

Management

- Airway
- Breathing
- Circulation

Airway

- Endotracheal intubation

  Adverse effect

  1. Sedative drugs (facilitate intubation)
     - Arterial vasodilatation, venodilation, or myocardial suppression
  2. Positive-pressure ventilation
     - reduces preload and CO

  – 1 + 2 = Hemodynamic collapse

  – Manage by : volume resuscitation and vasoactive agents

Breathing

- Mechanical ventilation
  - Adequate oxygenation, improvement of hypercapnia, and assisted, controlled, synchronized ventilation
  - Decrease the work of breathing and improve survival
- Arterial blood gas
  - Acid–base status, oxygenation, and ventilation.
- Neuromuscular blocking agents
  - Decrease respiratory muscle oxygen consumption and preserve O2 to vital organs
  - Severely hypoxemic due to acute respiratory distress syndrome

Circulation

- Fluids
- Vasopressors

Fluids

- Large-bore peripheral venous lines
- Most shock patients : Volume deficits exceptional cardiogenic shock with pulmonary edema
- 20 – 30 ml/kg of isotonic crystalloid
- Central line : assess volume, Scvo2, long term vasopressor route
- Position
  - Trendelenburg :
    - not improve cardiopulmonary performance
    - worsen pulmonary gas exchange
  - Passive leg raising above the level of the heart : may be effective

Vasopressors

- Inadequate response to volume resuscitation , contraindications to volume infusion
- Most effective when the vascular space is “full”

TABLE 12-7 Commonly Used Vasoactive Agents (all vasopressors increase myocardial oxygen demand; most should be titrated to desired effect)

Drug	Dose	Action	Cardiac Contractility	Vasoconstriction	Vasodilation	Cardiac Output
Dobutamine	2.0–20.0 micrograms/kg/min	β_1, some β_2 and α_1 in large dosages	++++	+	++	Increases
Side effects and comments	Inotrope only; Causes tachydysrhythmias, occasional GI distress, hypotension in volume-depleted patients; has less peripheral vasoconstriction than dopamine; can cause fewer arrhythmias than isoproterenol					
Dopamine	0.5–20 micrograms/kg/min	α, β, and dopaminergic	++ at 2.5–5 micrograms/kg/min	++ at 5–20 micrograms/kg/min	+ at 0.5–2.0 micrograms/kg/min	Usually increases
Side effects and comments	Tachydysrhythmias; a cerebral, mesenteric, coronary, and renal vasodilator at low doses; Surviving Sepsis Campaign second line, lot of overlap with α/β/dopaminergic receptors and dose; can be given through a peripheral IV					
Epinephrine	2–10 micrograms/min	α and β	++++ at 0.5–8 micrograms/kg/min	++++ at >8 micrograms/kg/min	+++	Increases
Side effects and comments	Causes tachydysrhythmia, leukocytosis; increases myocardial oxygen consumption; may increase lactate; no real maximum dose					

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Side effects and comments	Tachydysrhythmias; a cerebral, mesenteric, coronary, and renal vasodilator at low doses; Surviving Sepsis Campaign second line, lot of overlap with α/β/dopaminergic receptors and dose; can be given through a peripheral IV					
Epinephrine	2–10 micrograms/min	α and β	++++ at 0.5–8 micrograms/kg/min	++++ at >8 micrograms/kg/min	+++	Increases
Side effects and comments	Causes tachydysrhythmia, leukocytosis; increases myocardial oxygen consumption; may increase lactate; no real maximum dose					