Arterial catheterization in neonates and children

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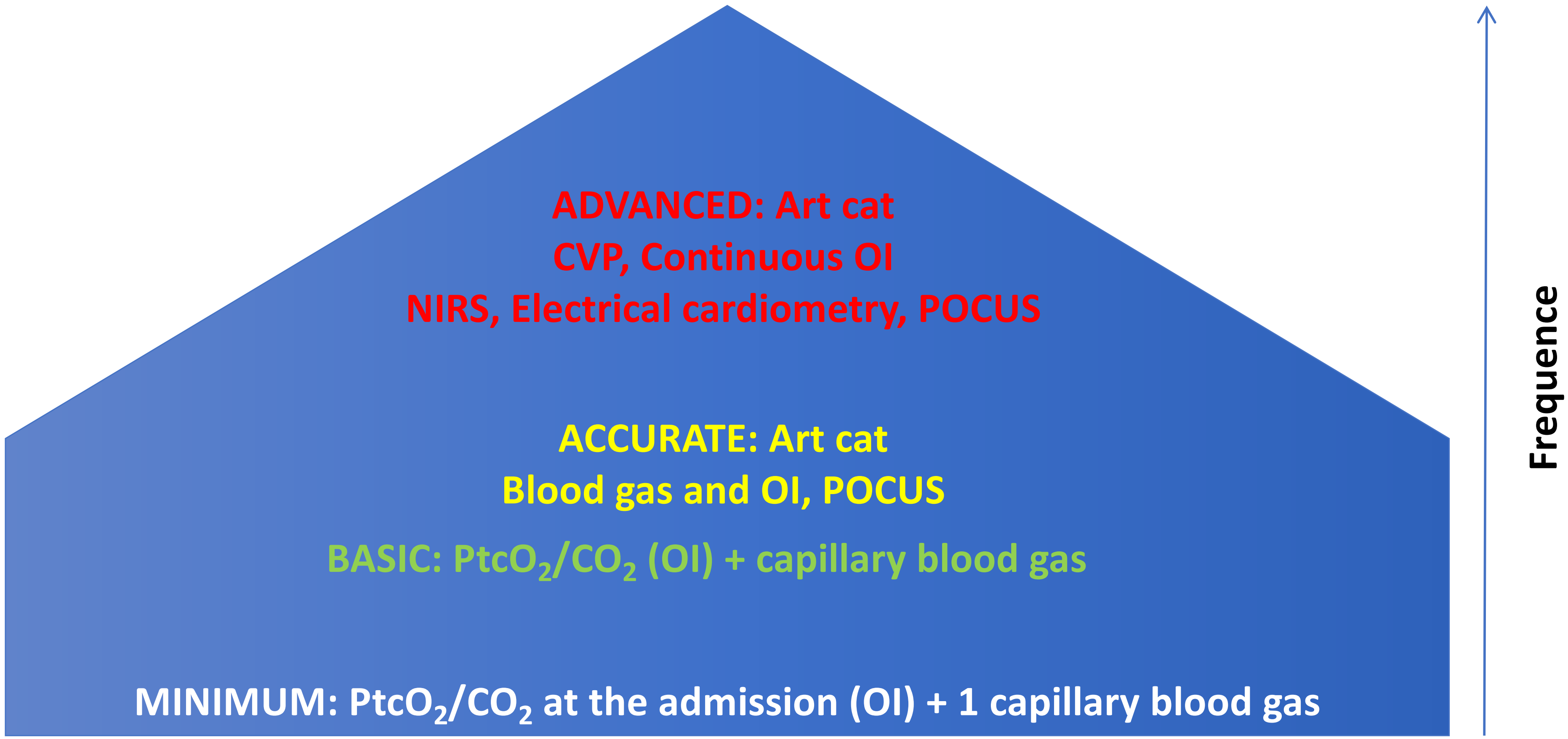
No conflict of interest to disclose.

other than…

Personalised monitoring (Paris Pyramide)



De Luca D et al, J Puericolture 2015


Lehna
REA-7
Néonat.
138
55/ 19
(44)
57/ 41
(49)
(5)
1.26
93
92
0.19
9
3.4
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NIHON KOHDEN


117
57/ 35
92
44
37
84
86

Personalising care of acute respiratory distress syndrome according to patients' age

	Neonatal definition: Montreux	Paediatric definition: PALICC	Adult definition: Berlin
Age	From birth until 44 weeks, or until 4 weeks, postnatal age (for neonates born after 40 weeks, postmenstrual age)	Beyond the period covered by Montreux definition and until adolescence*	Adults
Timing	Acute onset (ie, within 1 week) from a known or suspected clinical insult	Acute onset (ie, within 1 week) from a known or suspected clinical insult	Acute onset (ie, within 1 week) from a known or suspected clinical insult
Imaging	Diffuse, bilateral, and irregular opacities or infiltrates, or complete opacification of the lungs, which are not fully explained by local effusions, atelectasis, infant respiratory disease,† transient tachypnoea of the neonate, or congenital lung anomalies	New infiltrates consistent with acute parenchymal process; No need for bilaterality	Bilateral opacities not fully explained by effusions, lobar or lung collapse, or nodules
Origin of oedema	Not fully explained by congenital heart disease (this includes ductus arteriosus with pulmonary overflow if no acute pulmonary haemorrhage exists)	Not fully explained by cardiac failure or fluid overload	Not fully explained by cardiac failure or fluid overload
Severity classes	According to oxygenation index classes (same classes as the PALICC definition)	According to PaO_2:FIO_2 ratio or oxygenation or oxygen saturation index classes (depending on ventilation strategy, with preference for PaO_2)	According to PaO_2:FiO_2 ratio classes

Similarities and differences are evident and based on the best knowledge of ARDS biology and physiopathology across patients' age. ARDS=acute respiratory distress syndrome. PALICC=Pediatric Acute Lung Injury Consensus Conference. PaO_2:FiO_2= partial pressure of oxygen to fractional concentration of oxygen inspired air. *Both the PALICC and Berlin definitions can be used for adolescents or young adults, according to clinicians' experience. †Hyaline membrane disease or primary surfactant deficiency.

Table: **The three definitions of ARDS by age group**

De Luca D. Lancet Resp Med 2018

Infectious risk
Thrombotic risk
Blood loss risk

Continuous pressure monitoring
Accurate blood gas
Frequent blood sampling
Avoid interpretation errors in complex care

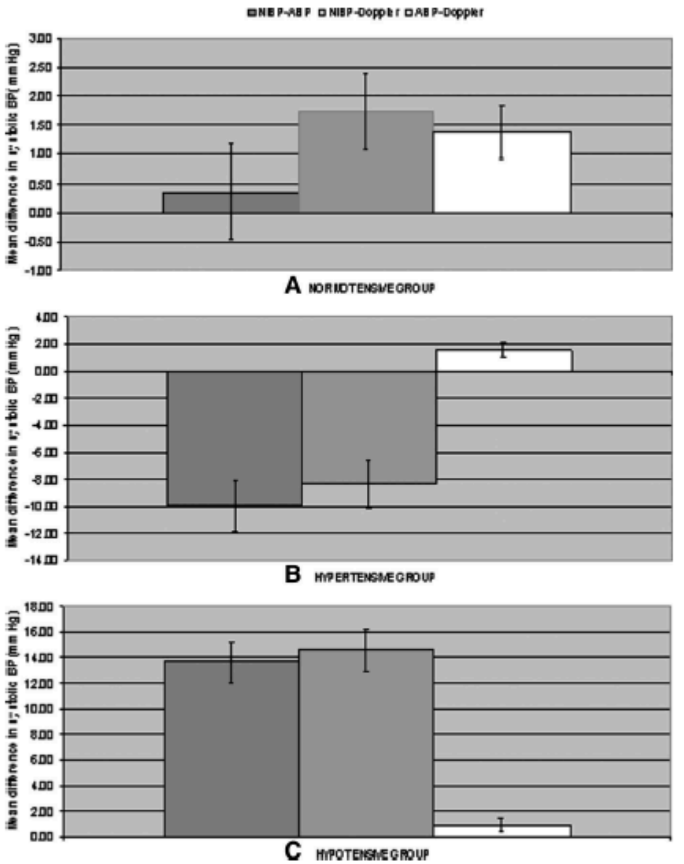

Figure 2. Difference in systolic arterial blood pressure between methods (indirect blood pressure using the Phillips automated oscillometric device [NIBP]–arterial blood pressure [ABP], NIBP–Doppler ultrasound, and ABP–Doppler ultrasound): mean and SE of mean (mm Hg). A, Normotensive; B, hypertensive; C, hypotensive subjects.

Dannevig I. Acta Paediatr 2005
Holt TR et al, Pediatr Crit Care Med 2011

Table 1
Distribution of arterial catheter placement from 1998 to 2002 ($n = 1574$)

	<5 kg [n (%)]	*5–10 kg* [n (%)]	*10–20 kg* [n (%)]
Right radial artery	271 (44.6)	381 (57.1)	163 (53.2)
Left radial artery	119 (19.8)	135 (20.2)	96 (31.2)
Right brachial artery	112 (18.6)	83 (12.4)	26 (8.4)
Left brachial artery	88 (14.6)	59 (8.8)	18 (5.8)
Right femoral artery	2 (0.3)	3 (0.4)	2 (0.6)
Left femoral artery	7 (1.2)	3 (0.4)	2 (0.6)
'Cut down' (right brachial artery only)	2 (0.3)	–	–

Schindler E. Ped Anesthesia 2005

Journal de pédiatrie et de puériculture (2015) **28**, 276—300

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ARTICLE ORIGINAL

Monitorages physiopathologiques en réanimation néonatale

CrossMark

Biomonitoring in neonatal critical care

D. De Luca[a,*], O. Romain[a], N. Yousef[a],
D. Andriamanamirija[a], S. Shankar-Aguilera[a],
E. Walls[a], B. Sgaggero[a], N. Aube[a], P. Tissières[b]

Indications:

- **Hemodynamic instability**
- **Severe/moderate NARDS or anyway OI>20**
- **PPHN**
- **Whole body hypothermia**
- **Need for AV – EXT**
- **Post surgical care of CHD babies**

Contraindications:

- Recent or contemporary cannulation of another artery in the same limb
- Negative Allen's test
- Local infection
- Local malformation

Different types

Small cannulae → Radial / Posterior tibial / Pedidia

Specific umbilical catheters → «Central» / High or low

(Femoral/brachial/temporal catheters)

Rarely used…more dangerous…

- **Hypercoagulation, hyperreactive tissues**
- **No collateral circulation**
- **Higher infectious risk (femoral)**
- **Higher occlusion risk (brachial and temporal)**

Cannulation of the temporal artery in neonates and infants

doi:10.1111/j.1460-9592.2006.02188.x

The benefit of cannulation of the TA is that the TA swelling and occasionally pulsation are easily observed under the skin in neonates and infants. In addition, as the TA supplies several branches on the scalp in the frontotemporal region, there is more scope to cannulate compared with other cannulation sites.

2007 Blackwell Publishing Ltd, *Pediatric Anesthesia*, **17**, 703–711

Those who ignore the past

doi:10.1111/j.1460-9592.2007.02392.x

SIR — I have read the recent correspondence by Jimi and Shin (1) in which they recommend superficial temporal arterial cannulation in infants. As someone who was a pediatric trainee in the 1970s and who had significant experience with this technique, I must agree that it is quite readily performed, either percutaneously or by cut down. However, I also distinctly and to this day remember the CT scans published by Prian *et al.* (2), which the authors reference, and also the particularly impressive CT scan of a massive infarction in the distribution of the middle cerebral artery published by Simmons *et al.* (3), which Jimi and Shin did not reference. The use of this technique decreased markedly and abruptly with the publication of these two reports. I note that the three patients reported by

Prian et al, J Pediatr 1978

Table 2
Mean duration of arterial catheterization, multiple punctures, the use of guide wires and the different size of cannulas used in pediatric patients

Body weight	*Mean duration*[a] *(days)*	*Multiple punctures* [n (%)]	*Use of guide wire* [n (%)]	*24-G catheter* [n (%)]	*22-G catheter* [n (%)]	*20-G catheter* [n (%)]
<5 kg	5.8 ± 4.3[b]	200 (33.3)[c]	79 (13.1)	362 (60.2)	239 (39.8)	0
5–10 kg	3.2 ± 3.9	142 (21.3)	67 (10.0)	289 (43.3)	371 (55.6)	7 (1.0)
10–20 kg	2.9 ± 2.2	44 (14.3)	17 (5.5)	97 (25.6)	203 (65.9)	8 (2.6)

[a]Mean ± SD; [b]$P < 0.05$ compared with children with 10–20 kg; [c]$P < 0.05$ compared with all other groups.

Table 3
Complications following arterial cannulation ($n = 1574$)

Body weight	*Permanent ischaemic damage* (n)	*Temporary occlusion* [n (%)]	*Sepsis* (n)	*Local infection* [n (%)]	*Pseudoaneurysm* (n)	*Hematoma* [n (%)]	*Bleeding* (n)
<5 kg	0	2 (0.3)	0	3 (0.5)	0	12 (2)	0
5–10 kg	0	3 (0.4)	0	5 (0.7)	0	22 (3.3)	0
10–20 kg	0	1 (0.3)	0	7 (2.3)	0	31 (10.1)	0

Table 3: Clinical characteristics and outcome at follow-up

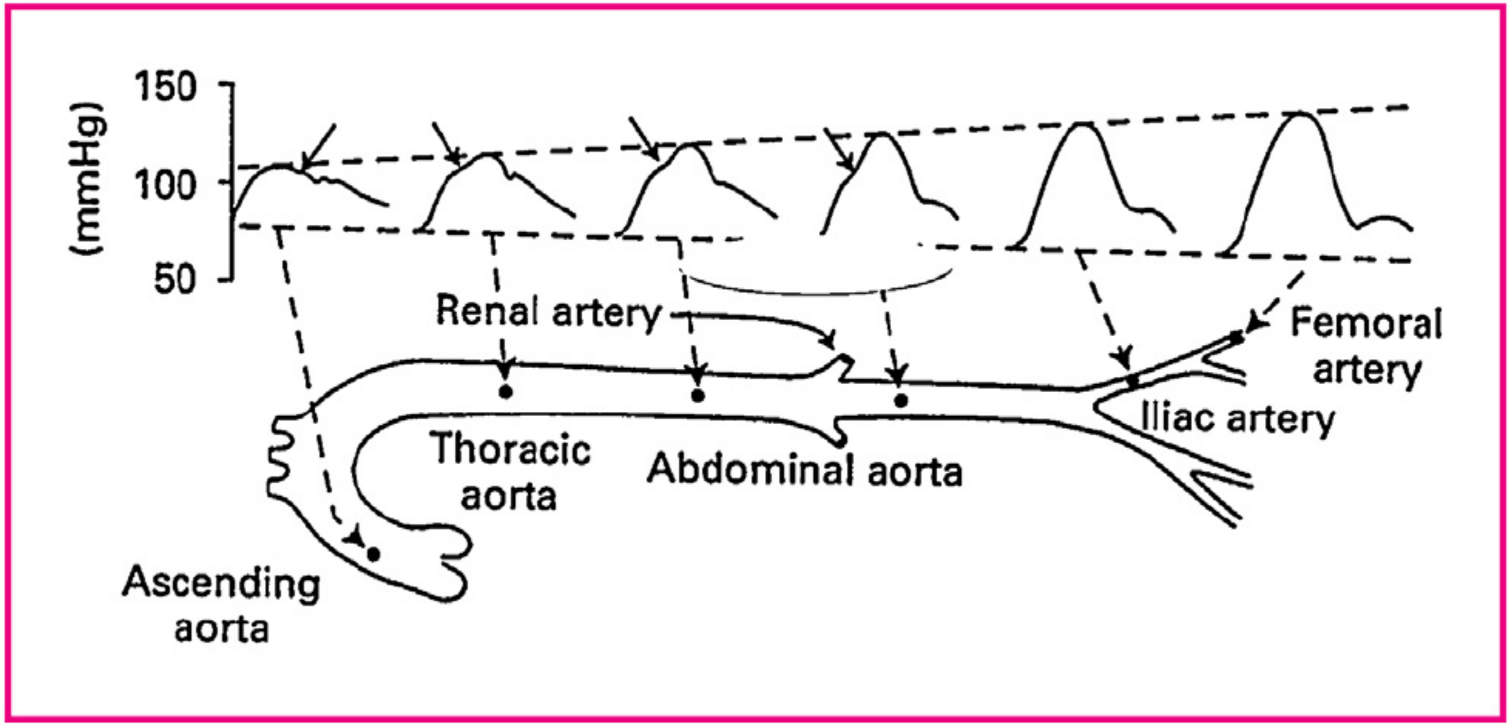
Patient Demographic								Outcome			
Patient	PMA [weeks]	Birth weight [g]	Sex	Diagnosis	Anatomic Site	Age at follow-up [years]	Surgery	Impairment of Extremity Function	Impairment of Sensitivity (heat/touch)	VSS	Cosmetic Result
1	23 + 2	520	m	PPHN, Sepsis	Right posterior tibial artery	2.0	-	-	-	0	good
2	23 + 3	716	f	Peripheral pulmonary stenosis, sepsis	Right radial artery	5,4	-	-	-	0	very good
3	23 + 4	660	m	NEC, PDA	Right radial artery	0,8	-	-	-	3	good
4	23 + 5	584	f	Aortic Coartation, arterial Hypotension	Right radial artery	1,1	-	-	-	2	poor
5	23 + 6	560	f	PPHN, PDA, sepsis	Left posterior tibial artery	2,0	Amputation of left forefoot	Retraction of achilles tendon	-	6	fair
6	24 + 1	760	m	PDA, sepsis	Right radial artery	3,4	-	Impaired pinch grip	-	2	good
7	24 + 6	650	f	PPHN, sepsis	Right radial artery	1,7	-		-	3	poor
8	24 + 6	795	m	RDS, sepsis	Right radial artery	2,2	-	-	-	0	very good
9	25 + 4	1120	m	TTTS (Aceptor), RDS, sepsis	Umbilical artery	4,9	-	Diffuse swelling and deformity of foot	-	4	fair
10	25 + 4	750	f	FFTS (Aceptor), PPHN, mekoniumileus, acute renal failure	Right radial artery	2,8	-	-	-	0	very good
11	26 + 1	892	m	RDS, septic shock	Right radial artery	1,9	-	-	-	0	very good
12	28 + 4	1390	f	Congenital AV-block, arterial hypotension	Right radial artery	2.8	-	-	-	0	very good
13	28 + 6	1170	m	ASD, AS, sepsis	Left femoral artery	2,9	Partial amputation Dig I,IV,V, necrosectomy lower leg and split thickness skin graft	Pes equinus	Hyperaesthesia	14	fair
14	35 + 4	2140	f	Esophageal atresia (type IIIb), RDS	Left radial artery	2,6	Necrosectomy forearm and split thickness skin graft	-	Hypaesthesia	5	poor
15	37 + 2	3565	f	Asphyxia	Right radial artery	3,3	-	-	-	0	very good
16	39 + 4	2300	f	Pierre-Robin Sequence, chromosomal translocation, sepsis, DIC	Right radial artery	4,4	-	-	-	0	very good

##

Schindler E et al. Ped Anesthesia 2005
Deindl P et al, Acta Paediatr 2018

Be careful….

- **In most neonates**
- **In neonates and infants with ductal dependent CHD**

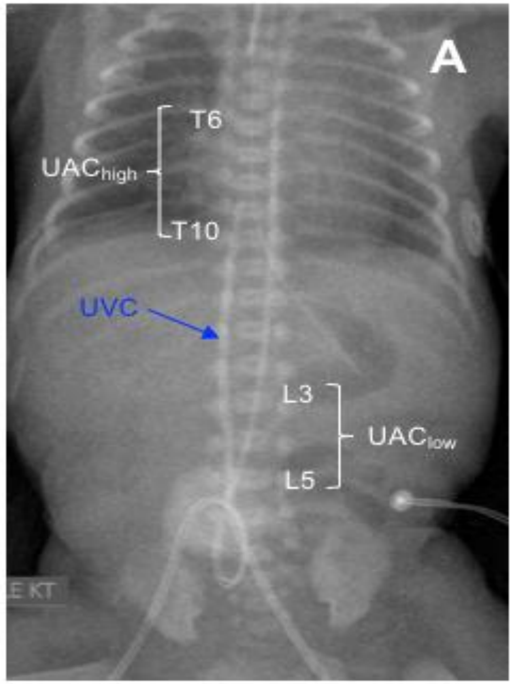


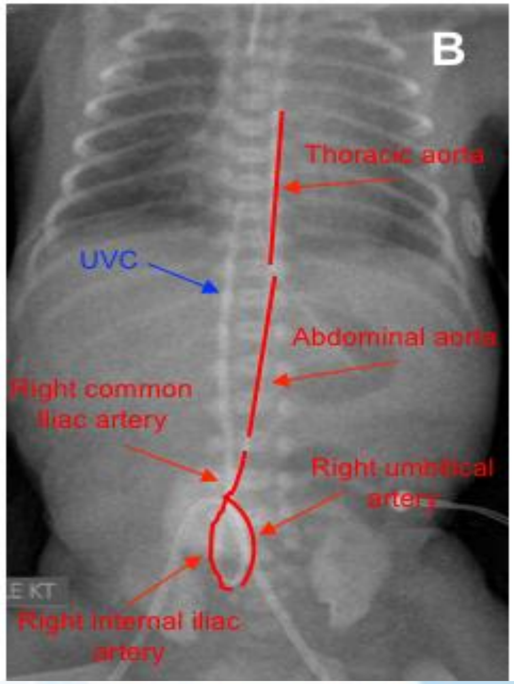
De Luca D et al, J Puericolture 2015

Thanks to Elise

24G/22G

26G





Dell'Orto, Centorrino, De Luca in Pittiruti – Springer Verlag in press

YES!

- Nurses' training ++++
- Nursing protocol +++
(with frequent checks)
- Straight line
- Small mouvements are relevant
- Attention to…tension!

De Luca D et al, J Puericolture 2015

Many open questions

What is the best artery to cannulate

What is the best method to cannulate, to do nursing and maintain it?

Others…

What is the best artery to cannulate

It depends on…

- Patients' age and condition
- Local situation
- Skills

650 arteries
(infant population –
mean age 6 months)

20 thrombosis (3.2%)

Newborn age (OR 6.57 [2.30–18.8]
***p*<0.001**
Hematocrit (OR 3719.77 [3.74–3695246]
***p*=0.02**
Low cardiac output (OR 2.92 [0.98–8.7]
***p*=0.05**
associated with femoral thrombosis

Table 2 Characteristics of indwelling arterial catheters placed in the femoral artery and in other locations

Characteristics	Femoral location, $n = 137$	Other locations, $n = 470$	P-value
Diameter of catheter (mm)	0.91 (0.10)	0.82 (0.17)	< 0.001
Length of catheter (mm)	74.42 (18.77)	25.34 (8.48)	< 0.001
Duration of placement (h)	97.59 (106.42)	72.11 (112.19)	0.01
More than two puncture attempts	43 (33.6)	72 (16.5)	< 0.001
Cardiac disease	87 (63.5)	243 (51.7)	0.01
Cyanotic cardiac disease	45 (51.7)	91 (19.4)	0.02
Low cardiac output	69 (50.4)	145 (31)	< 0.001
Anticoagulation	51 (37.2)	110 (23.5)	0.001
Hematocrit	0.37 (0.77)	0.38 (0.79)	NS
Surgery	99 (73.9)	353 (75.4)	NS
Thrombotic events	18 (13.1)	2 (0.4)	< 0.001

Brotschi B et al, J Thromb Haemost 2011

Many open questions

What is the best artery to cannulate

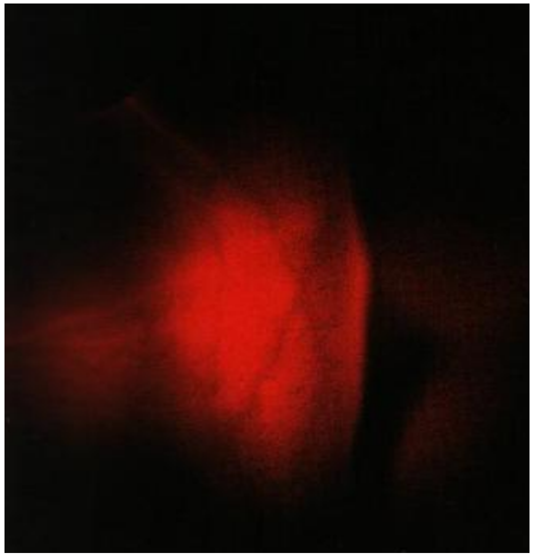
What is the best method to cannulate, to do nursing and maintain it?

Others…



Cold light (<35°C) penetrating tissue: vessels usually shown as dark purple or brown

Radial



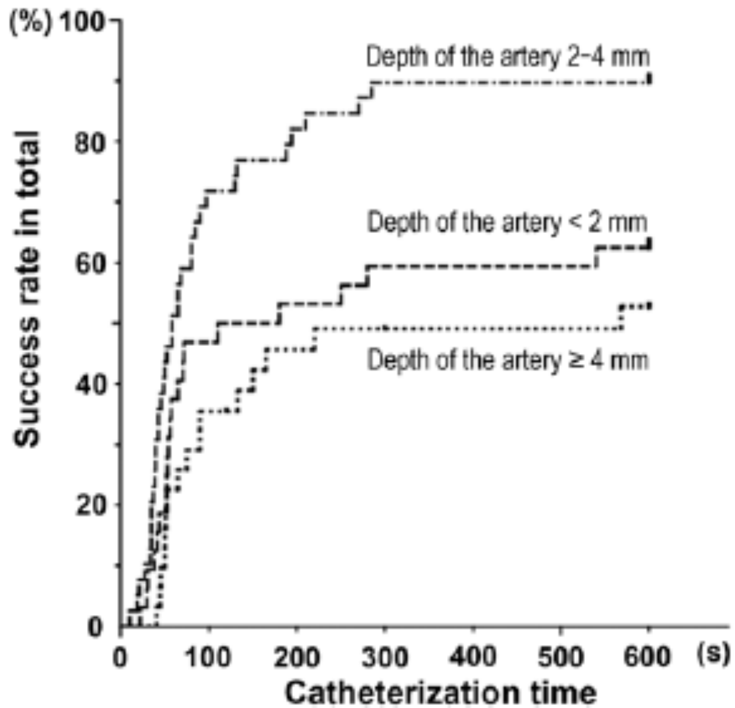
Posterior Tibial

Table 2 Paediatric study characteristics. SAOOP, short axis out of plane. *Level of evidence assessed using the Centre for Evidence-Based Medicine levels of evidence introduction document.[13] †Same patient with each radial artery cannulated

Study	Number of patients (ultrasound/control)	Age group	Ultrasound technique	Operator	Indication	Primary outcome(s)	Level of evidence*
Ganesh and colleagues (2009)[19]	152 (72/80)	99 months (mean)	SAOOP	Anaesthetists with fewer than 10 previous ultrasound-guided attempts	Operating theatre	1. First-attempt success 2. Number of attempts 3. Time 4. Number of cannulae used	1
Ishii and colleagues (2013)[7]	59 (59/59)†	18.4 months (mean)	SAOOP	Anaesthetists with no previous ultrasound-guided arterial cannulation experience	Operating theatre	1. First-attempt success 2. Number of attempts 3. Time 4. Complications	1
Schwemmer and colleagues (2006)[4]	30 (15/15)	28 months (median)	SAOOP	Anaesthetists with >20 previous ultrasound-guided arterial cannulations	Operating theatre	1. First-attempt success 2. Number of attempts 3. Time	1
Tan and colleagues (2015)[6]	40 (20/20)	<24 months	Either SAOOP or long axis in plane	Anaesthetic fellows with unknown experience	Operating theatre	1. Number of attempts 2. Time 3. Cost 4. Number of cannulae used	1
Ueda and colleagues (2013)[5]	104 (52/52)	5–6 months (mean)	SAOOP	Anaesthetists with fewer than five previous ultrasound-guided attempts	Operating theatre	1. First-attempt success 2. Time 3. Complications	1

Nakayama Y et al, Anest Analgesia 2016
White L et al, Br J Anesthesia 2016

Optimal depth technique



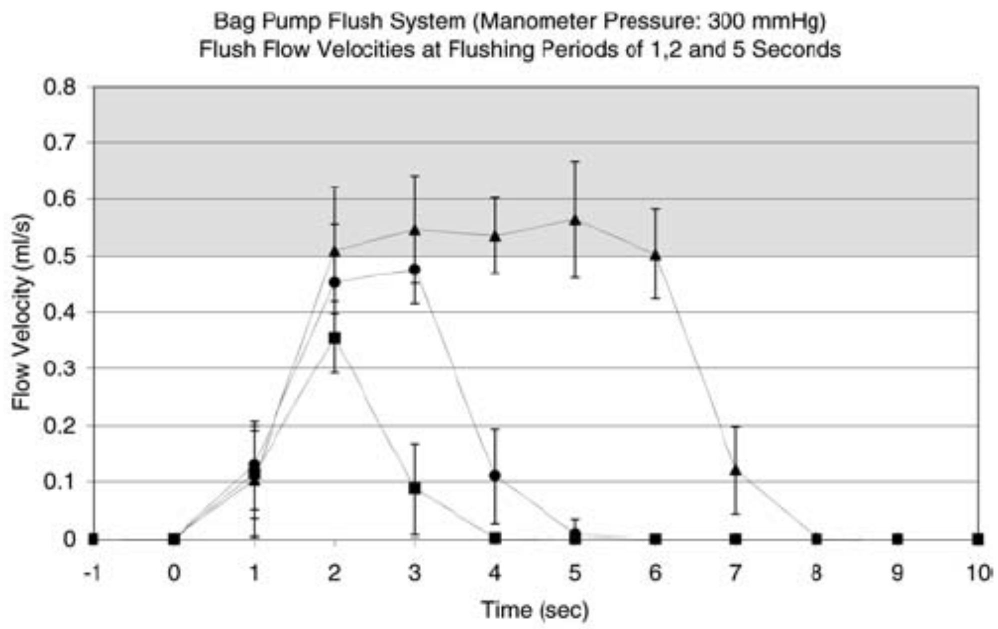
Hanging drop technique

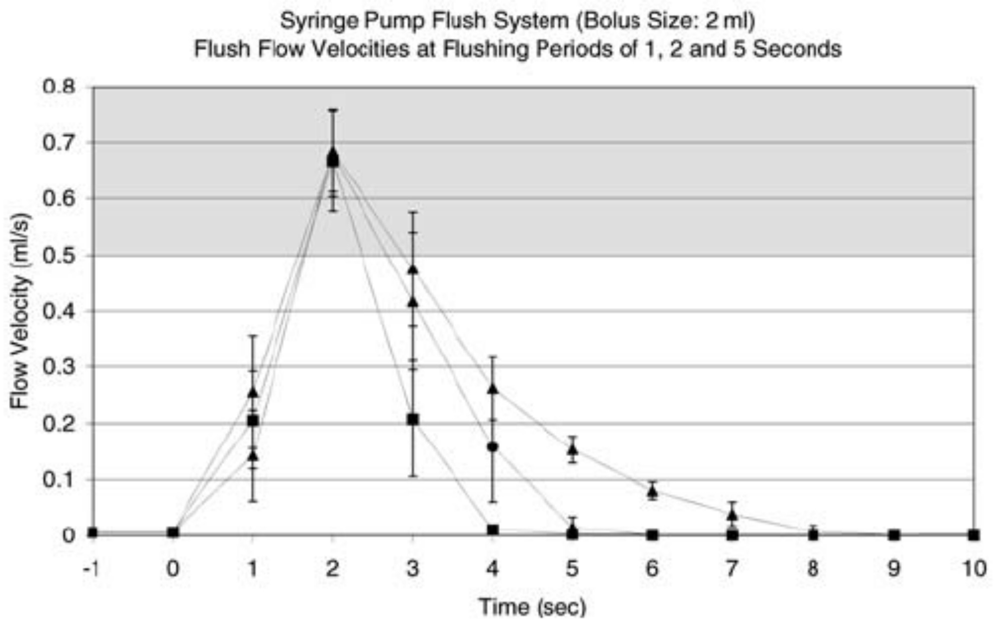
Nakayama Y et al, Anest Analgesia 2016
Kundu R et al, Ped Anesthesia 2016

Flush > 0.5 mL/h risks of retrograde embolization if:

- 22G
- Too large volume
- Too long time

Usually electronic pumps preferred for fluid restrictions…





Cornelius A et al, Intensive Care Med 2002
Cornelius A et al, Ped Anesthesia 2002

Many open questions

What is the best artery to cannulate

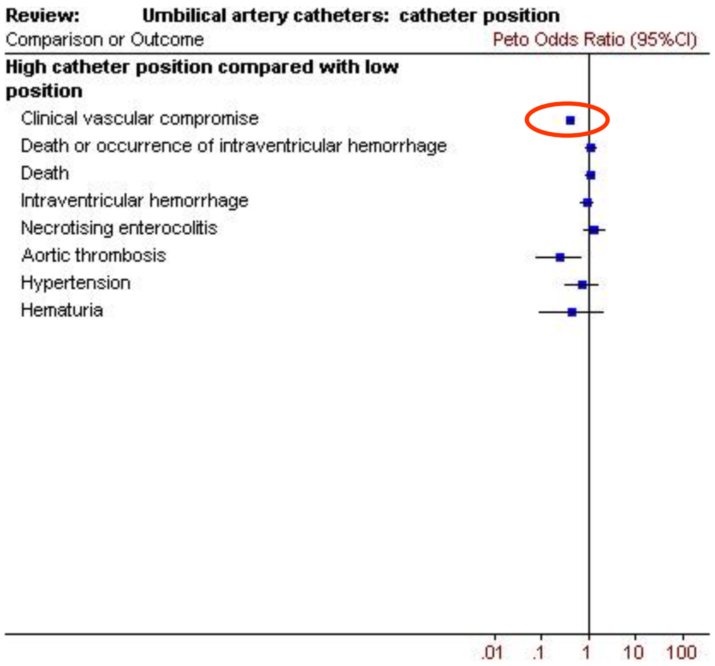
What is the best method to cannulate, to do nursing and maintain it?

Others…

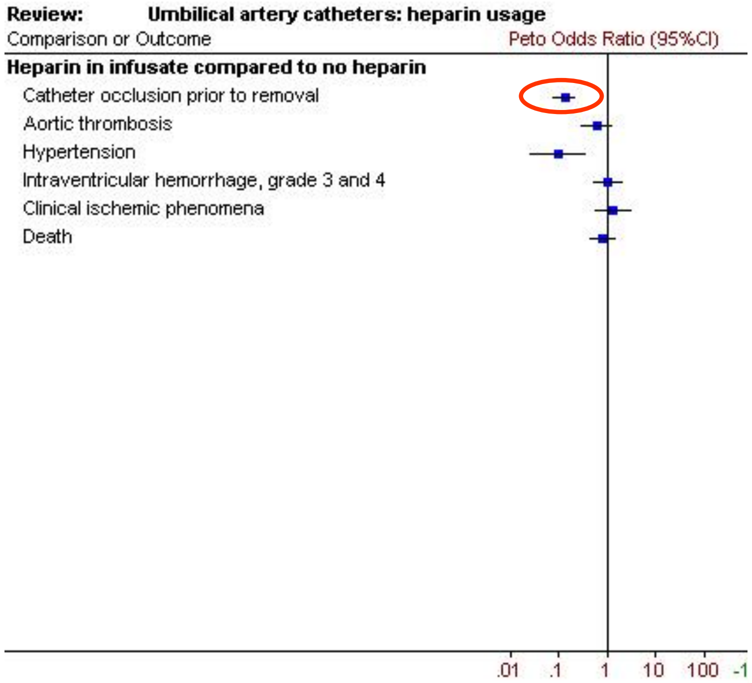
Arterial lines are placed by MD…
… but afterwards nursing is ESSENTIAL !

The particular case of UAC…

High (T9-T10) vs Low (L3-L4)



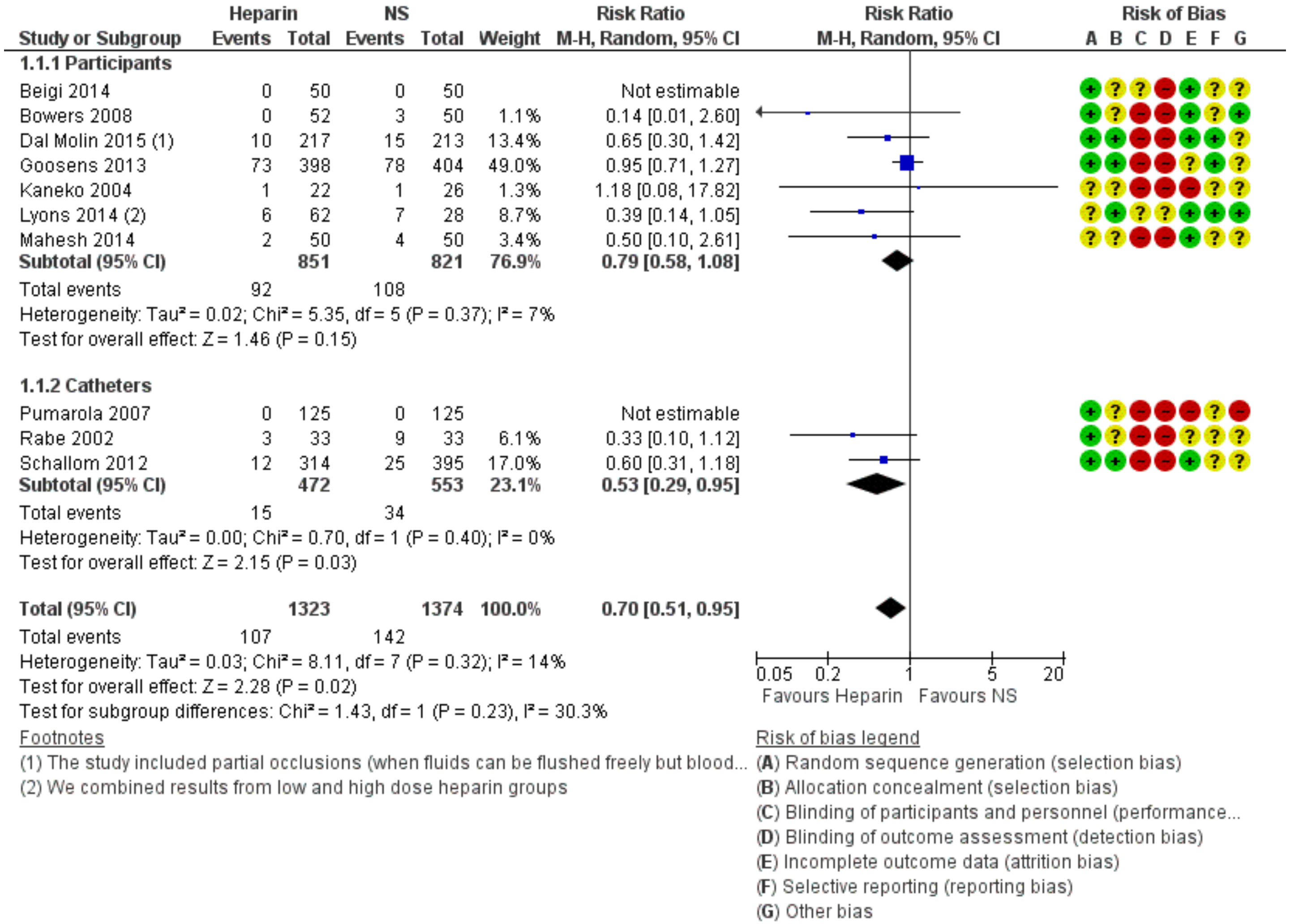
Heparine vs no Heparine

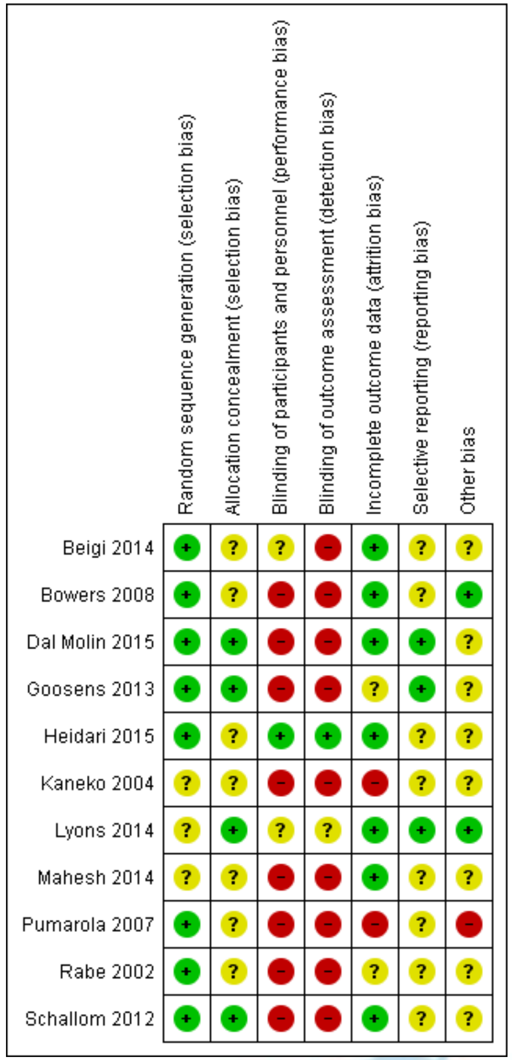


Beware of UAC contraindications ! (ARED/AED, abdominal malformations)

Cochrane Database Syst Rev 2000

And the peripheral arteries…

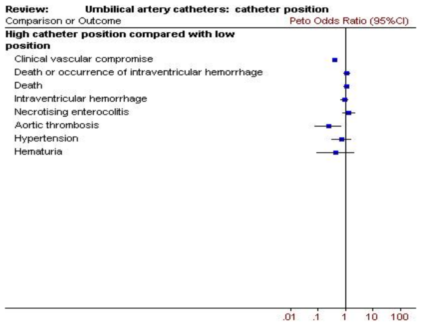




Cochrane Database Syst Rev 2018

Bradford NK et al, Int J Nurs Stud 2016

High (T9-T10) vs Low (L3-L4)



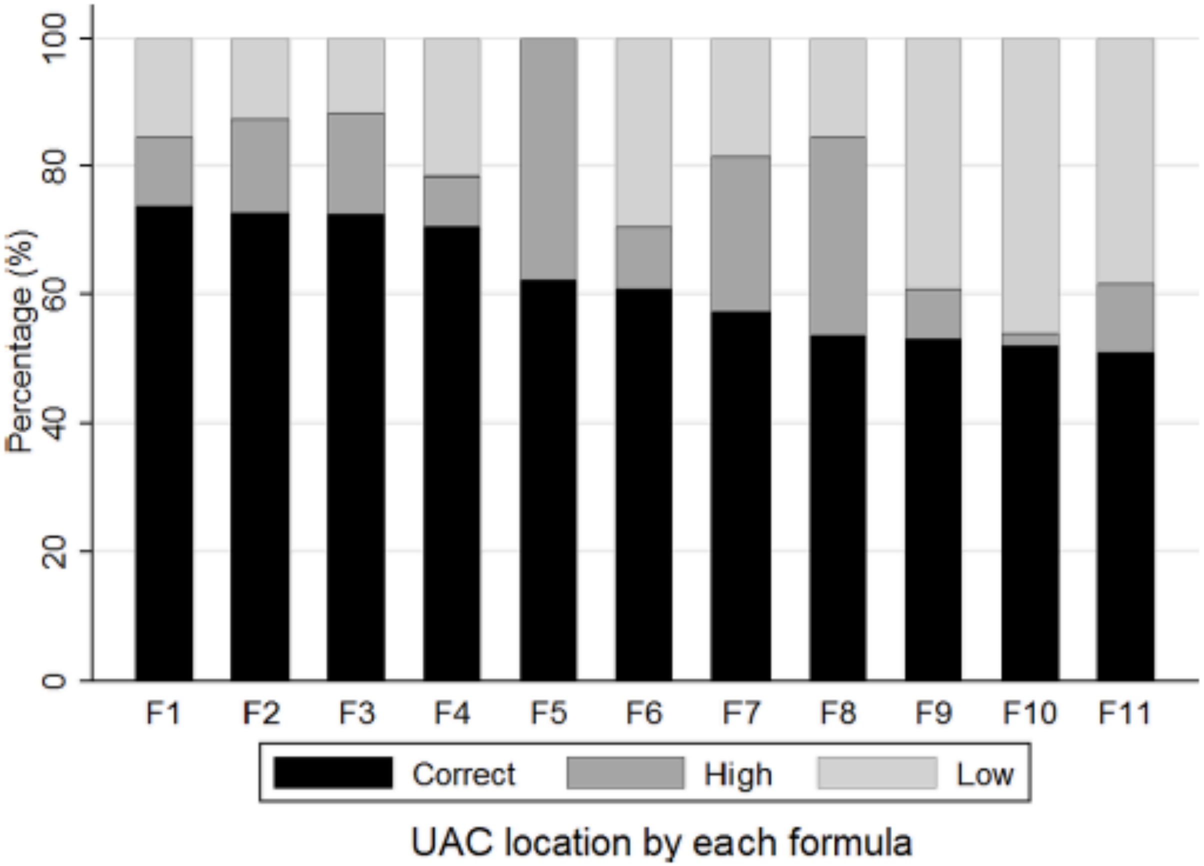


Figure 2 Predicted rates of correct positioning of UAC (T6–T10), high position (above T6) and low position (below T10) by using each formula. UAC, umbilical arterial catheter.

Lean WL et al, Arch Dis Child Fetal Neonatal Ed 2017

MAX 5 d

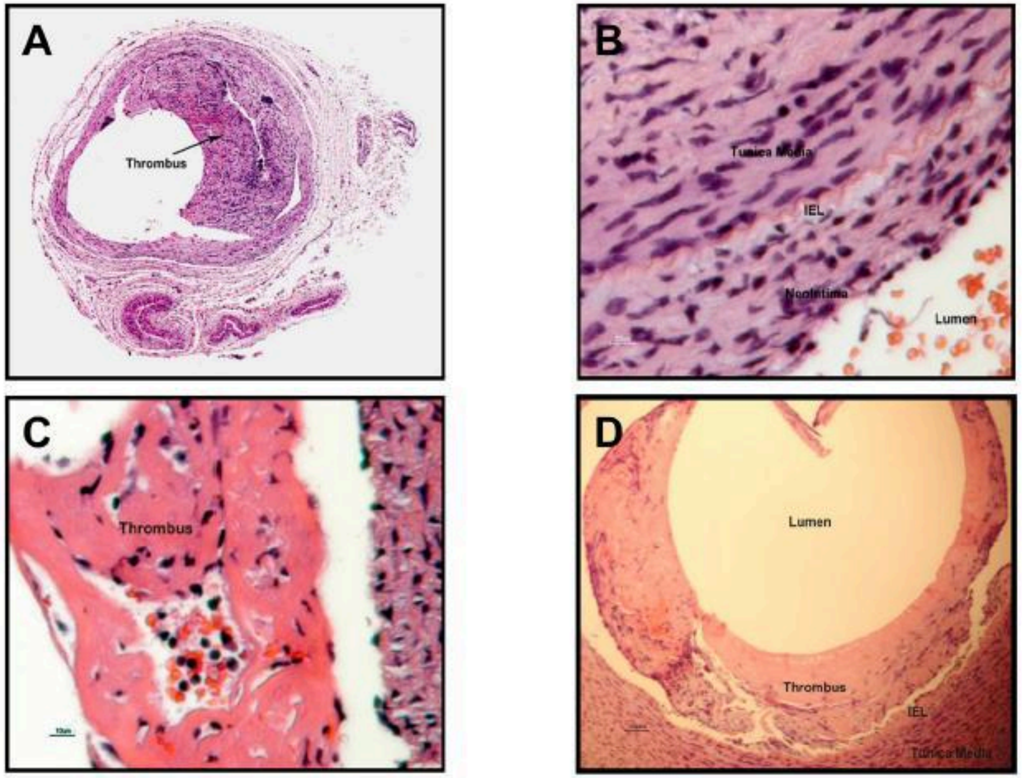


Figure 2.
Photomicrographs of hematoxylin and eosin-stained aorta sections from 6 d & 14 d UAC animals displaying neointimal hyperplasia and thrombus formations adjacent to the internal elastic lamina (IEL). Panels: A) Lower aorta, 14 d animal (× 4); B) Lower aorta, 14 d animal (× 20); C) Middle aorta, 6 d animal (× 20); D) Middle aorta, 14d animal (× 4).

McAdams RM et al, J Perinatol 2009

Fletcher MA, et al. Umbilical arterial catheter use: report of an audit conducted by the Study Group for Complications of Perinatal Care. *Am J Perinatol 1994;11:94-9.*

Study Group for Complications of Perinatal Care
survey of 13 US NICUs

UAC = 30% of NICU admissions
Mean duration 4.9 days
Varibility in catheter type, position and policy

Adverse events inversely correlated with BW (*p*<0.001)
and to the abdominal placement (*p*<0.05)

The issue of blood drawing through UAC

Max 0.5 mL/min

Author/year	Study type/design	Methodology	Population/Sample size	Outcome variables	Level of evidence (see Box 1)	Findings with statistical significance
Umbilical artery catheter trial study group[10] (1992)	Prospective, multicenter randomized group trial	Randomization scheme for equal numbers of high UACs or low UACs placed within the first 6 h of life	970 neonates birthweights: 500–1499 481: high 489: low	Stratified by weight groups IVH grades: 0–I, II–IV, in survivors and those who died Complications	Level II[a]	Increased risk of vascular complications with low placement in general. No difference in IVH/death
Lott et al[12] (1996)	Prospective, single center, nonrandomized, pre/posttest measurements	Measurement of cerebral blood flow velocity in the anterior cerebral artery using Doppler ultrasound, in VLBW infants during sampling with UACs in high and low position (20 seconds/2ml)	30 infants, < 1501 g at 24 h of life (within 6 h)	Cerebral blood flow velocity as calculated with AUVC (area under the velocity curve) and PI (pulsatility index)	Level IV[b]	Decreased cerebral blood flow velocity both high and low during sampling-greater in high; increased CBFV in high during instillation.
Roll et al[13] (2000)	Prospective, single center, nonrandomized, descriptive	NIRS (near infrared spectroscopy) changes in cerebral blood volume and oxygenation during sampling from UACs. (no specified rate of sampling)	20 infants, < 1501 g, DOLO-2 with a UAC	Concentrations of oxygenated Hgb (O_2Hb), deoxygenated Hgb (HHb), and cytochrome oxidase. to measure cerebral blood volume	Level IV[b]	O_2Hb decreased significantly from baseline. HHb did not change significantly.
Schultz et al[15] (2003)	Prospective, single-center, nonrandomized, descriptive	Measures of O_2Hb, HHb, tissue oxygenation index (TOI), with 2 blood samplings at 2 speeds, 20 and 40 s	20 infants, preterm with high UACs (median gestational age 30.14 wk, median wt 1170 g	O_2Hb, HHb, TOI	Level IV[b]	O_2Hb and TOI decreased with 20 s sampling. No change with 40-s sampling.
Roll et al (2006)[22]	Prospective, single-center, nonrandomized, descriptive	NIRS, measure O_2Hb, HHb during sampling with specified volumes (mL) and velocities: 1.6 to clear over 80 or 40 s, 1.7 asp over 40 or 80 s, or 0.2 over 30 s, and 1.6 to reinstill over 30 s, and 0.6 to flush over 6 s	48 infants, mean wt 965 g, mean age 27 wk	Cerebral blood volume and cerebral oxygenation	Level IV[b]	With all 3 methods of sampling O_2Hb decreased significantly, HHb did not change

08:45 – 11:00 **1st SESSION: LUNG ULTRASOUND AND CARDIOPULMONARY INTERACTIONS**
Chairs: Nadya Yousef, Yasser Elsayed

08:45 – 09:15 *The FALLS and SESAME Protocols*
Daniel Lichtenstein – Paris, France

09:15 – 09:45 *Lung Ultrasound scores to guide Mechanical Ventilation?*
Bélaïd Bouhemad – Paris, France

09:45 – 10:15 *Lung Ultrasound and extra – corporeal life support*
Matteo Di Nardo – Rome, Italy

10:15 – 10:45 *The use of lung ultrasound in patients with congenital heart defects"*
Javier Rodriguez – Fanjul – Barcelona, Spain

10:45 – 11:00 Discussion

11:00 – 11:30 coffee break and exposition visit

11:30 – 13:00 **2nd SESSION: LUNG ULTRASOUND AND LUNG MECHANICS**
Chairs: Luigi Cattarossi, Philippe Durand

11:30 – 12:00 *Can lung ultrasound help to understand lung mechanics of my patient?*
Daniele De Luca – Paris, France

12:00 – 12:30 *Lung ultrasound and restrictive conditions: Yes!*
Giovanna Chidini - Milan, Italy

12:30 – 13:00 *Lung ultrasound and obstructive conditions? Maybe...*
Daniele Biasucci – Rome, Italy

13:00 – 14:30 lunch break and exposition visit

14:30 – 16:00 **3nd SESSION: LUNG ULTRASOUND AND SPECIAL SITUATIONS**
Chairs: Daniele De Luca, Francesco Raimondi

14:30 – 15:00 *Use of lung ultrasound in pediatric/neonatal anesthesia?*
Giuseppe Staiti – Paris, France

15:00 – 15:30 *Lung ultrasound, a useful tool in pediatric ARDS?*
Philip Durand – Paris, France

15:30 – 16:00 *Lung ultrasound findings in neonatal malformations*
Nadya Yousef – Paris, France


Thanks for listening
daniele.deluca@aphp.fr