Ventilation in Cardiac Arrest :

The Future is NOW

Abdo Khoury MD, MScDM

Vice president, The European Society for Emergency Medicine

Vice president, International Pan Arab Critical Care Medicine Society

Department of Emergency Medicine & Critical Care

Bourgogne Franche-Comté University – Medical & Trauma Center, Besançon – France

akhoury@chu-besancon.fr

CHRU Besançon centre hospitalier régional universitaire

UBFC UNIVERSITÉ BOURGOGNE FRANCHE-COMTÉ

SAMU25 URGENCES

IPACCMS International Pan Arab Critical Care Medicine Society

EUSEM EUROPEAN SOCIETY FOR EMERGENCY MEDICINE


Greenland Sea
Norwegian Sea
Barents Sea
ICELAND
North Atlantic Ocean
IRELAND
Dublin
Bay of Biscay
SPAIN
Madrid
MOROCCO


UNITED KINGDOM
NETH.
BELGIUM
GERMANY
FLANDERS
Lille
Amiens
PICARDY
Le Havre

Conflict of interest

Research Grant for ventilation from the European Commission

Acknowledgments

- Pr. Patrick Plaisance
- Pr. Jean Christophe Richard
- Pr. Samir Jaber
- Dr Georges Boussignac
- Dr. Jean Claude Deslandes

Background

Cardiovascular diseases are the leading mortality cause in the world

Cardiac arrest counts:

- 500 000 deaths/year in Europe
- 60 000 in France

Mean survival rate of 5%

Members

American Heart Association
Learn and Live

EUROPEAN RESUSCITATION COUNCIL

HEART & STROKE FOUNDATION
Finding answers. For life.

Australian Resuscitation Council

NEW ZEALAND Resuscitation Council
WHAKAHAUORA AOTEAROA

RESUSCITATION COUNCIL OF SOUTHERN AFRICA

InterAmerican Heart Foundation

Resuscitation Council of Asia

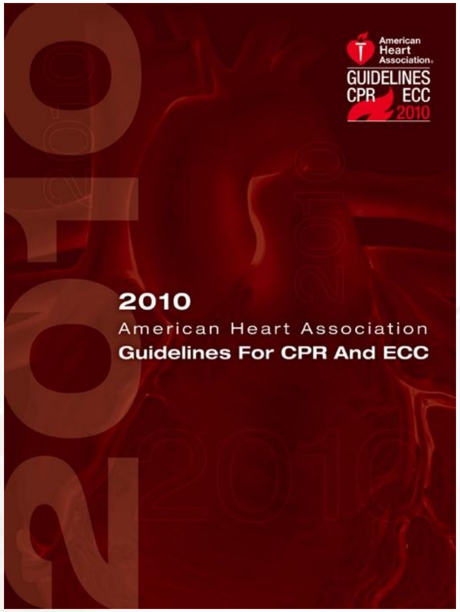
International Liaison committee on Resuscitation

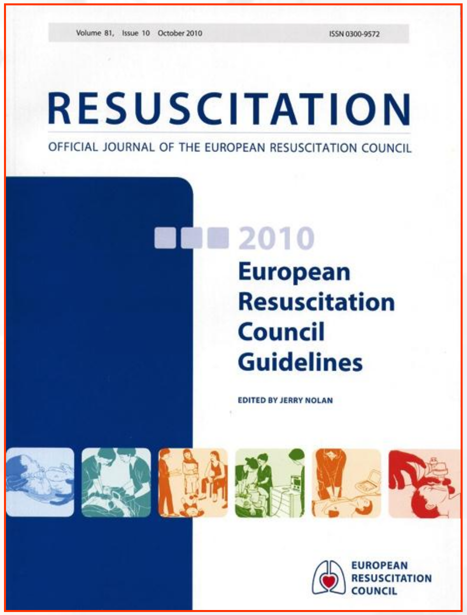
International Liaison Committee on Resuscitation
ILCOR

2015

American Heart Association
Learn and Live

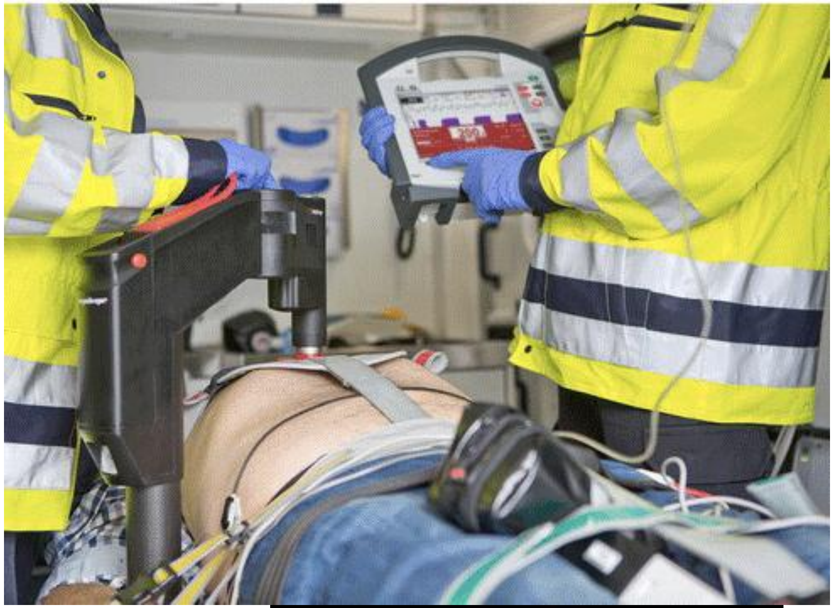
European Resuscitation Council





ILCOR give strong recommendations to improve survival

Mechanical compression devices



Minimal Interruption of chest compressions

…But What about ventilation?

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WHAKAHAUORA AOTEAROA

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InterAmerican Heart Foundation

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International Liaison committee on Resuscitation

Ventilation

BVM

Continuous

the self-inflating bag ventilates the patient's lungs with ambient air (21% oxygen). The delivered oxygen concentration can be increased to about 85% by using a reservoir system and attaching oxygen at a flow 10 l min^{-1}. There are no data to indicate the optimal arterial blood oxygen saturation (SaO_2) during CPR, and no trials comparing different inspired oxygen concentrations. In one observational study of patients receiving 100% inspired oxygen via a tracheal tube during CPR, a higher measured PaO_2 value during CPR was associated with ROSC and hospital admission.[541] The worse outcomes associated with a low PaO_2 during CPR could however be an indication of illness severity. Animal data and observational clinical data indicate an association between high SaO_2 after ROSC and worse outcome (Section 5 – Post-resuscitation care).[273,542–544]

After ROSC, as soon as arterial blood oxygen saturation can be monitored reliably (by blood gas analysis and/or pulse oximetry), titrate the inspired oxygen concentration to maintain the arterial blood oxygen saturation in the range of 94–98%. Avoid hypoxaemia, which is also harmful – ensure reliable measurement of arterial oxygen saturation before reducing the inspired oxygen concentration. This is addressed in further detail in Section 5 – post resuscitation care.[273]

Suction

Use a wide-bore rigid sucker (Yankauer) to remove liquid (blood, saliva and gastric contents) from the upper airway. Use the sucker cautiously if the patient has an intact gag reflex; pharyngeal stimulation can provoke vomiting.

Choking

The initial management of foreign body airway obstruction (choking) is addressed in Section 2 – basic life support.[223] In an unconscious patient with suspected foreign body airway obstruction if initial basic measures are unsuccessful use laryngoscopy and forceps to remove the foreign body under direct vision. To do this effectively requires training.

Ventilation

Advanced Life Support providers should give artificial ventilation as soon as possible for any patient in whom spontaneous ventilation is inadequate or absent. Expired air ventilation (rescue breathing) is effective, but the rescuer's expired oxygen concentration is only 16–17%, so it must be replaced as soon as possible by ventilation with oxygen-enriched air. The pocket resuscitation mask is similar to an anaesthetic facemask, and enables mouth-to-mask ventilation. It has a unidirectional valve, which directs the patient's expired air away from the rescuer. The mask is transparent so that vomit or blood from the patient can be seen. Some masks have a connector for the addition of oxygen. When using masks without a connector, supplemental oxygen can be given by placing the tubing underneath one side and ensuring an adequate seal. Use a two-hand technique to maximise the seal with the patient's face.

High airway pressures can be generated if the tidal volume or inspiratory flow is excessive, predisposing to gastric inflation and subsequent risk of regurgitation and pulmonary aspiration. The risk of gastric inflation is increased by:

- malalignment of the head and neck, and an obstructed airway;
- an incompetent oesophageal sphincter (present in all patients with cardiac arrest);
- a high airway inflation pressure.

Conversely, if inspiratory flow is too low, inspiratory time will be prolonged and the time available to give chest compressions is reduced. Deliver each breath over approximately 1 s, giving a volume that corresponds to normal chest movement; this represents a compromise between giving an adequate volume, minimising the risk of gastric inflation, and allowing adequate time for chest compressions. During CPR with an unprotected airway, give two ventilations after each sequence of 30 chest compressions.

Inadvertent hyperventilation during CPR is common. While this increased intrathoracic pressure[545] and peak airway pressures[546] in small case series in humans, a carefully controlled animal experiment revealed no adverse effects.[547] We suggest a ventilation rate of 10 min^{-1} during continuous chest compressions with an advanced airway based on very limited evidence.[4]

Self-inflating bag

The self-inflating bag can be connected to a facemask, tracheal tube or supraglottic airway (SGA). Without supplementary oxygen, the self-inflating bag ventilates the patient's lungs with ambient air (21% oxygen). The delivered oxygen concentration can be increased to about 85% by using a reservoir system and attaching oxygen at a flow 10 l min^{-1}.

Although a bag-mask enables ventilation with high concentrations of oxygen, its use by a single person requires considerable skill. When used with a face mask, it is often difficult to achieve a gas-tight seal between the mask and the patient's face, and to maintain a patent airway with one hand while squeezing the bag with the other. Any significant leak will cause hypoventilation and, if the airway is not patent, gas may be forced into the stomach.[548,549] This will reduce ventilation further and greatly increase the risk of regurgitation and aspiration.[550] The two-person technique for bag-mask ventilation is preferable. Several recent observational studies and a meta-analysis have documented better outcomes with use of bag-mask ventilation compared with more advanced airways (SGA or tracheal tube).[529,551–554] However, these observation studies are subject to significant bias caused by confounders such as advanced airways not being required in those patients who achieve ROSC and awaken early.

Once a tracheal tube or a SGA has been inserted, ventilate the lungs at a rate of 10 breaths min^{-1} and continue chest compressions without pausing during ventilations. The laryngeal seal achieved with a SGA may not be good enough to prevent at least some gas leaking when inspiration coincides with chest compressions. Moderate gas leakage is acceptable, particularly as most of this gas will pass up through the patient's mouth. If excessive gas leakage results in inadequate ventilation of the patient's lungs, chest compressions will have to be interrupted to enable ventilation, using a compression–ventilation ratio of 30:2.

Passive oxygen delivery

In the presence of a patent airway, chest compressions alone may result in some ventilation of the lungs.[555] Oxygen can be delivered passively, either via an adapted tracheal tube (Boussignac tube),[556,557] or with the combination of an oropharyngeal airway and standard oxygen mask with non-rebreather reservoir.[558] In theory, a SGA can also be used to deliver oxygen passively but this has yet to be studied. One study has shown higher neurologically favourable survival with passive oxygen delivery (oral airway and oxygen mask) compared with bag-mask ventilation after out-of-hospital VF cardiac arrest, but this was a retrospective analysis and is subject to numerous confounders.[558] Until further data are available, passive oxygen delivery without ventilation is not recommended for routine use during CPR.

Alternative airway devices

The tracheal tube has generally been considered the optimal method of managing the airway during cardiac arrest.[309] There is evidence that, without adequate training and experience, the incidence of complications, such as unrecognised

3 Questions :

1st Question :

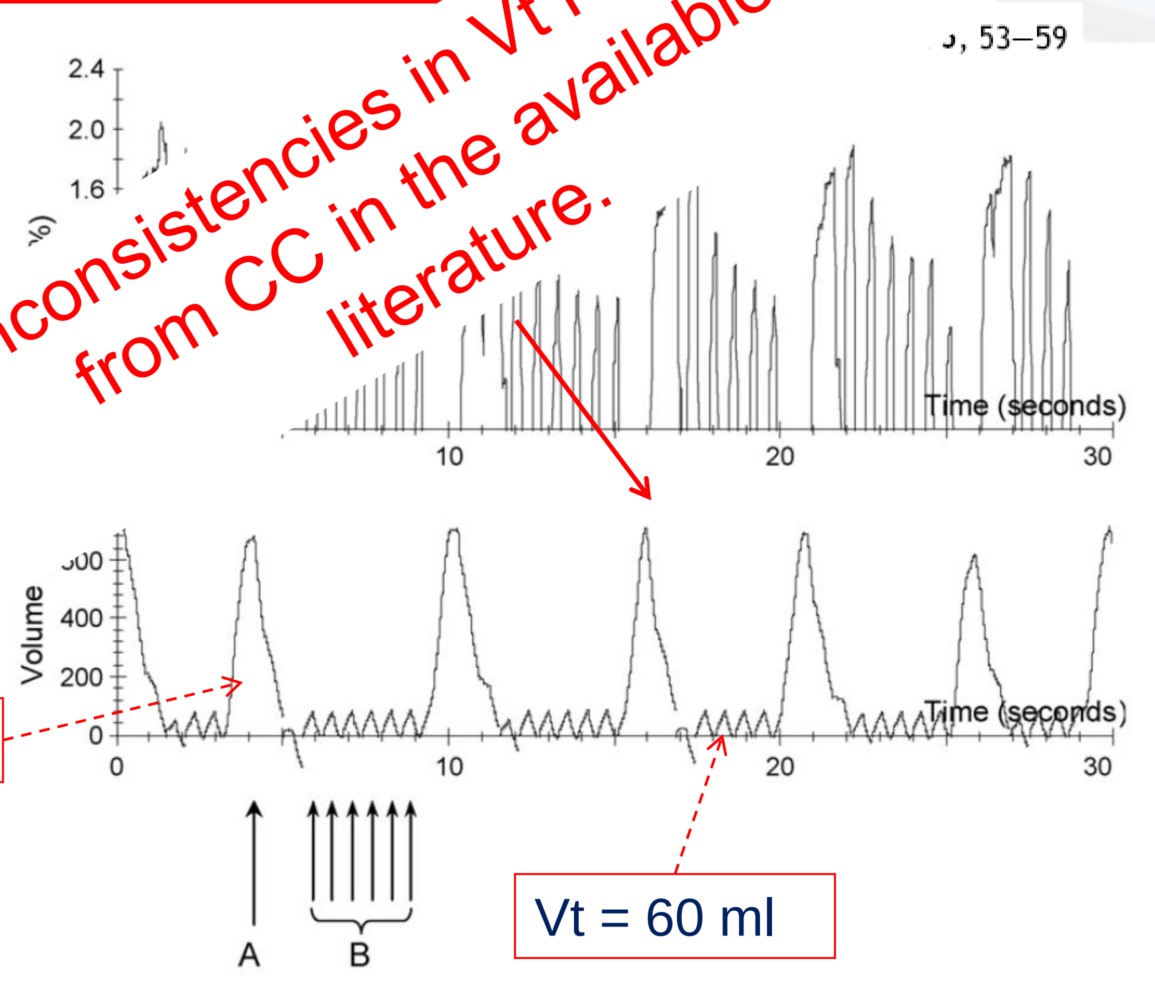
What if we don't ventilate?

Does compression-only cardiopulmonary resuscitation generate adequate passive ventilation during cardiac arrest?☆

Charles D. Deakin[a,*], John F. O'Neill[b], Ted T

- 17 patients
- CC: LUCAS 1
- ETT
- Manual Ventilation: Self-Inflating bag FiO_2 100%

Inconsistencies in Vt resulting from CC in the available literature.



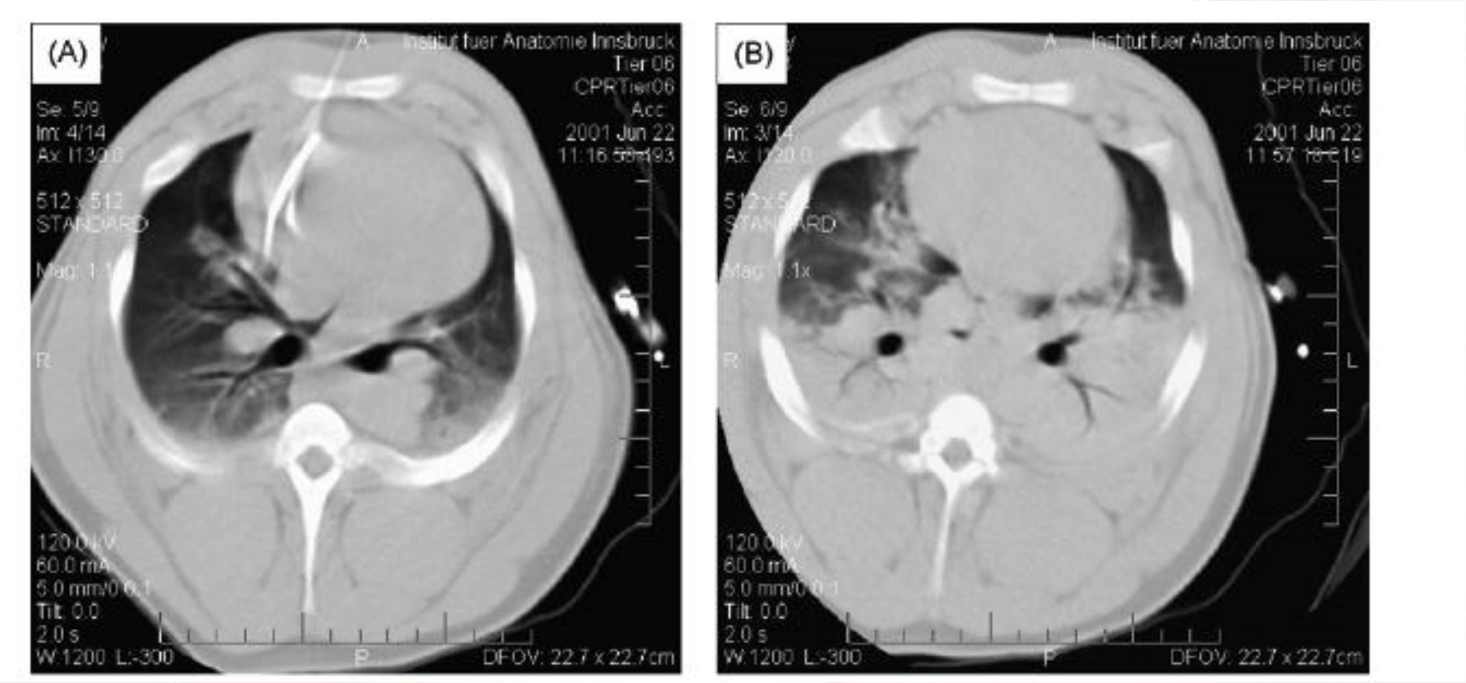
Vt = 700 ml

Vt = 60 ml

Pulmonary injury caused by CC without ventilation

Use of an inspiratory impedance threshold valve during chest compressions without assisted ventilation may result in hypoxaemia☆,☆☆

Holger Herff[a,*], Claus Raedler[a], Rolf Zander[b], Volker Wenzel[a], Christian A. Schmittinger[a], Erich Brenner[c], Michael Rieger[d], Karl H. Lindner[a]



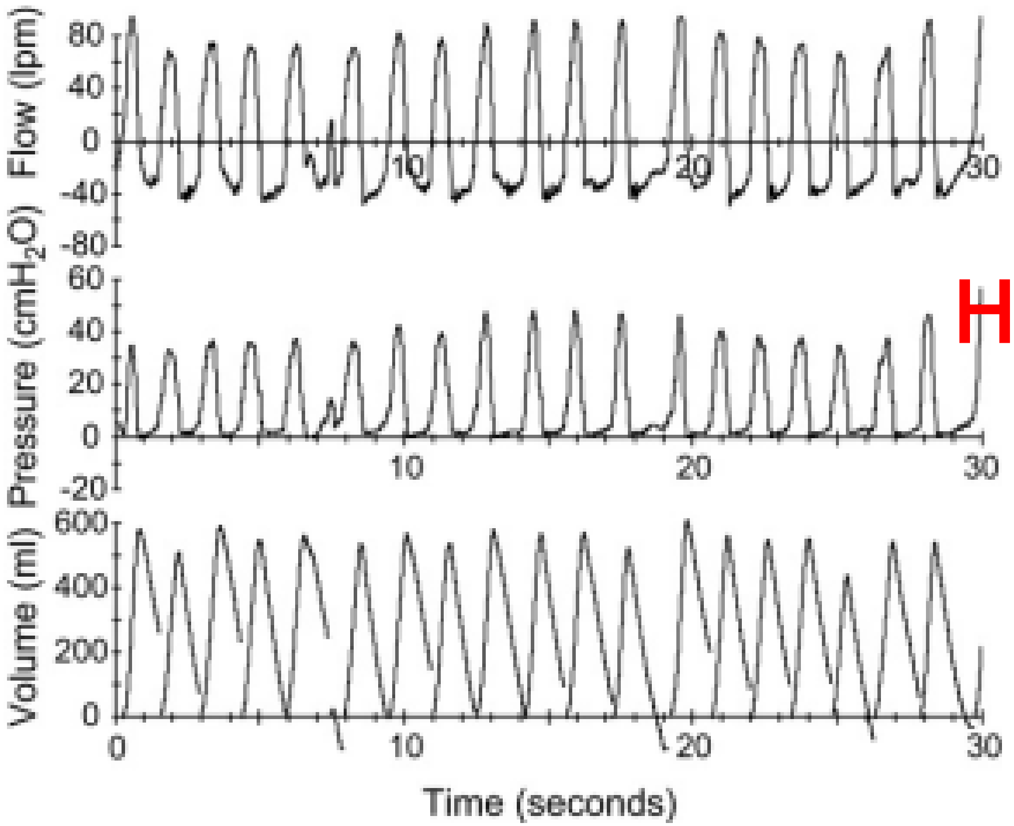
2nd Question :

What happens when we ventilate?

Do we hyperventilate cardiac arrest patients ?

Clinical observational study

12 patients OHCA



High airway pressure

RR = 40 / min

O'Neill J.F, Deakin C.D, Resuscitation 2007

Hyperventilation:

- Guidelines well known, but little observed in practice
- Frequency too high rather than excessive V_T

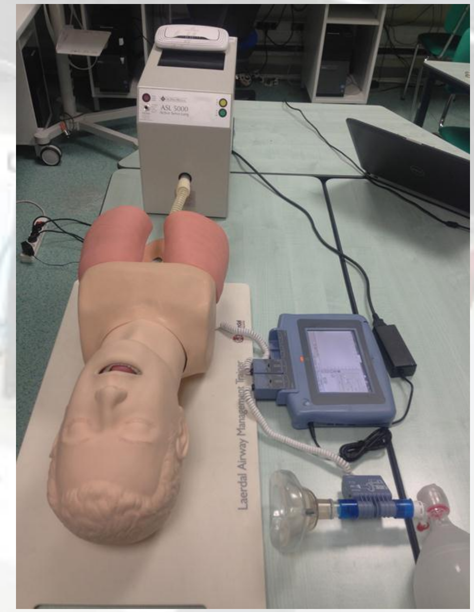
Abella BS. JAMA 2005;293:305-310

Bergrath, Resuscitation 2012, Volume 83, Issue 4, Pages 488–493

N. Marjanovic. RESPIRATORY CARE October 29, 2013

Factors affecting manual ventilation performance

140 Healthcare workers



- Simulation of a Respiratory Arrest Patient
- Ingmar ASL 5000
- Bag Valve Mask (5 min)
  - Ambu
  - Laerdal

A. Khoury et al, Biomed Research International, 2016

Factors affecting manual ventilation performance

BVM

Variable	Mean ± SD	Lower quartile	Upper quartile
Instantaneous ventilation rate (R_V, bpm)	24.09 ± 9.47	17.20	29.09
Tidal volume (V_T, ml)	333.94 ± 124.19	245.60	419.95
BVM insufflation volume (V_{ins}, ml)	590.20 ± 193.31	458.11	723.40
Gastric tidal volume (V_G, ml)	37.58 ± 25.13	18.92	52.43
Lung peak flow (PF_{Lung}, L/min)	39.99 ± 16.53	28.40	50.16
BVM peak flow (PF_{BVM}, L/min)	69.26 ± 28.07	49.16	85.92
Gastric peak flow (PF_G, L/min)	5.35 ± 4.33	2.53	7.34
Lung peak pressure (P_{peak}, cmH_2O)	4.81 ± 1.89	3.44	6.04
I_time (I, s)	0.76 ± 0.26	0.58	0.89
E_time (E, s)	2.10 ± 1.19	1.28	2.53

Table 2: Ventilation parameter values measured during all the 5 minute ventilation tests (n = 280), realized with 140 participants ventilating with to different BVM on a simulated apneic patient.

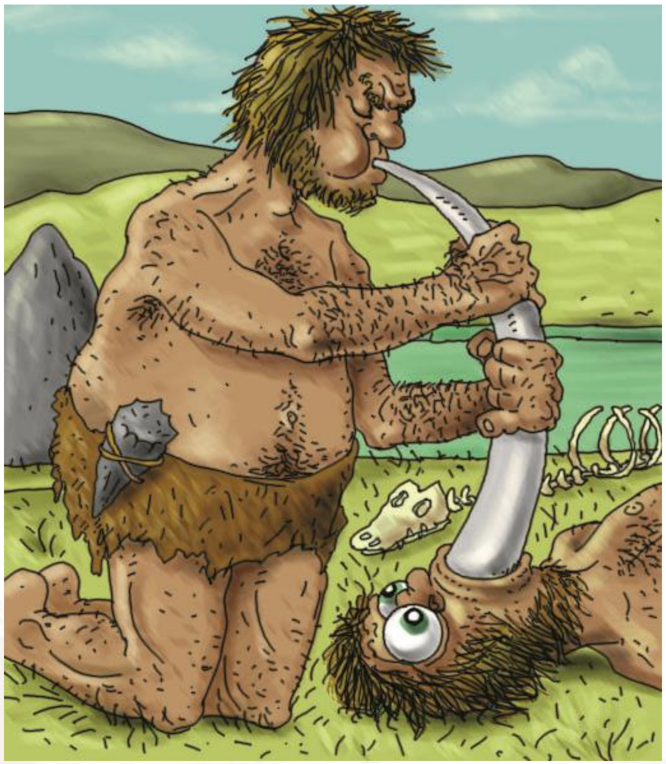
ETT

Variable	Mean ± SD	Lower quartile	Upper quartile
Instantaneous ventilation rate (R_V, bpm)	23.60 ± 9.66	16.27	29.09
Tidal volume (V_T, ml)	462.31 ± 155.42	361.40	545.01
BVM insufflation volume (V_{ins}, ml)	-	-	-
Gastric tidal volume (V_G, ml)	-	-	-
Lung peak flow (PF_{Lung}, l/min)	47.87 ± 20.06	34.35	57.81
BVM peak flow (PF_{BVM}, l/min)	-	-	-
Gastric peak flow (PF_G, l/min)	-	-	-
Lung peak pressure (P_{peak}, cmH_2O)	7.27 ± 2.93	5.26	8.60
I time (I, s)	0.88 ± 0.34	0.66	1.03
E time (E, s)	2.17 ± 1.31	1.27	2.63

Table 2: Ventilation parameter values measured during all the 5-minute ventilation tests (n = 280), realized with 140 participants ventilating with two different BVM on an intubated apneic patient.

A. Khoury et al, Biomed Research International, 2016

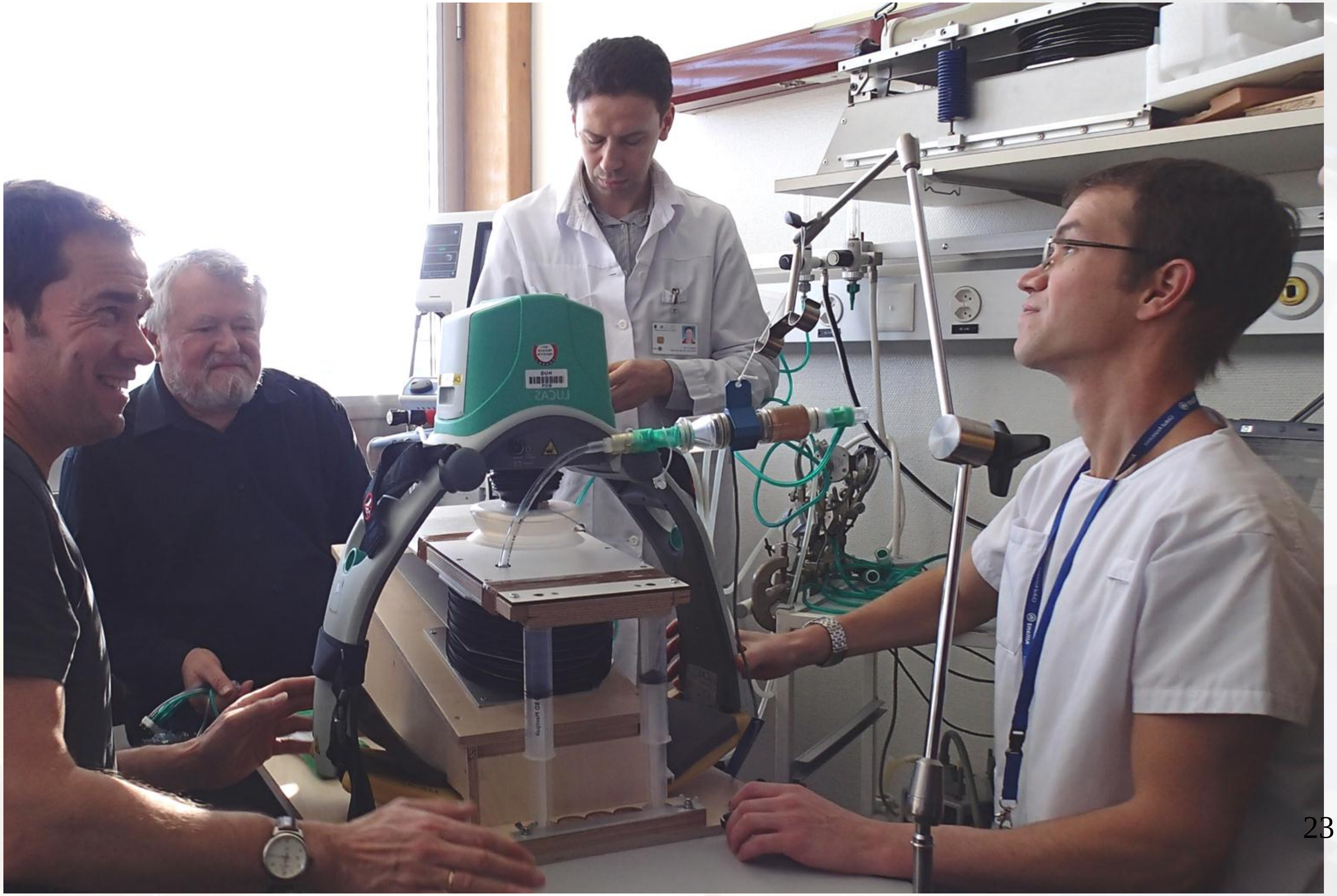
Hyperventilation



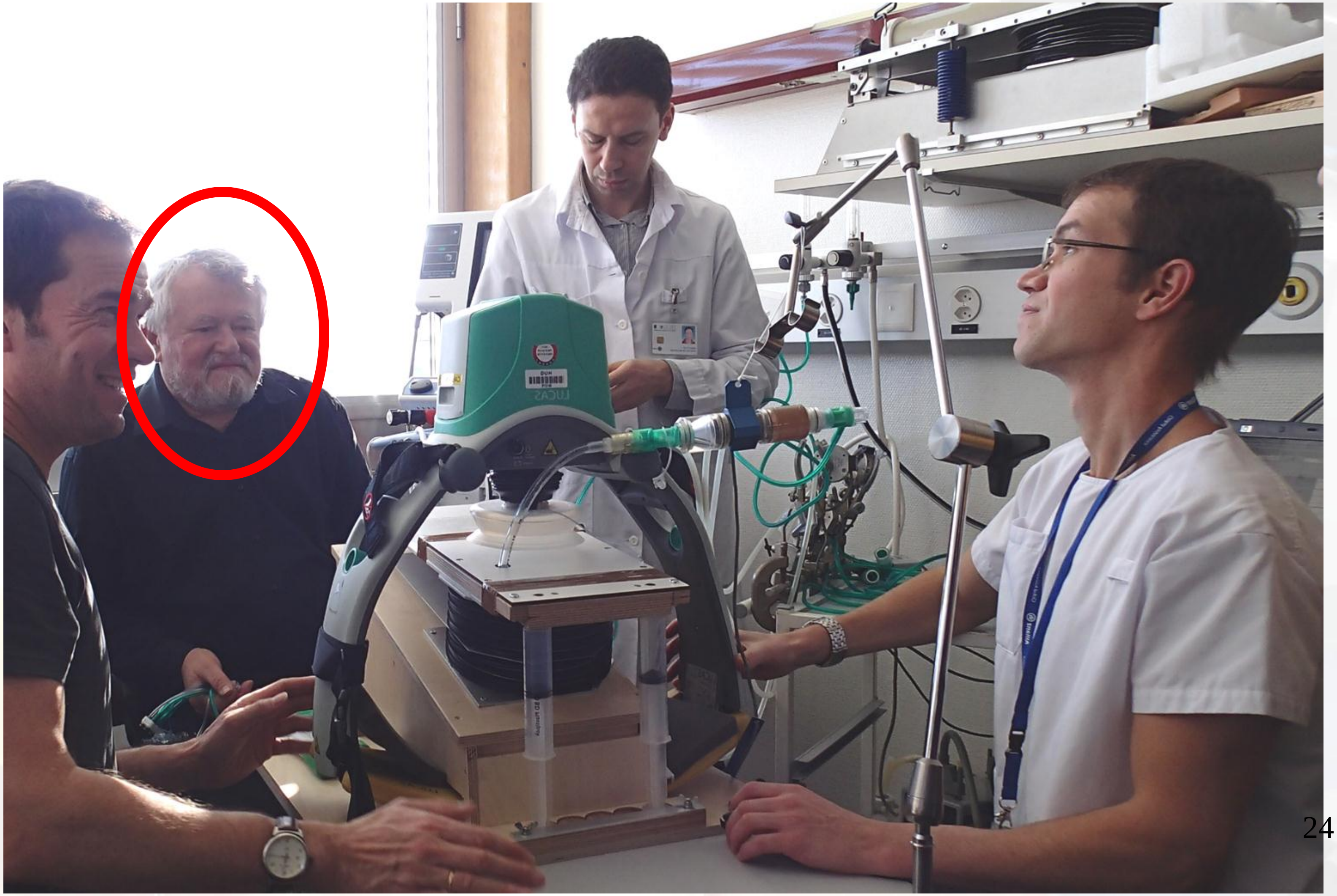
- ↗ Intrathoracic Pressure
- ↘ Coronary perfusion pressure
- ↘ venous return
- ↘ survival rate

Has a deleterious effect on blood flow during CPR

Are there solutions ?



Boussignac
Cardiac Arrest Respiratory Device

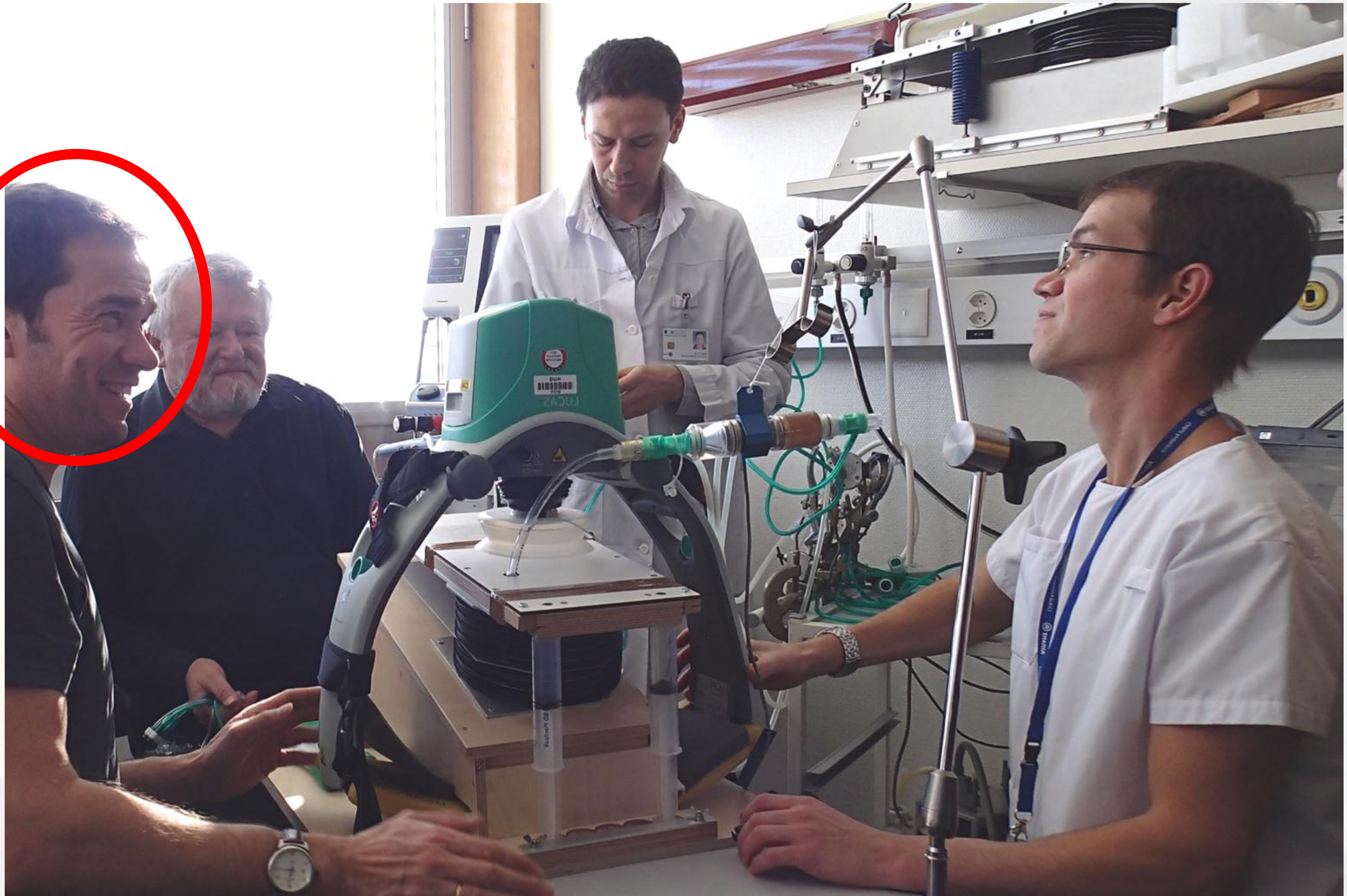


B card
(Boussignac)

But How to better optimise ventilation?

- Ideally >>>
- Synchronization to Chest Compressions:
  - Compression = Insufflation time
  - Decompression = Exsufflation time

JC Richard
Cardio Pulmonary Ventilation



CPV

CARDIO PULMONARY VENTILATION

INT
EXT
00:02:20
v1.5.0
Demonstration
Pression (cmH2O)
Gel
60
30
0
0
6
12
18
Débit (L/min)
t(s)
160
0
-160
fCT
c/min
120
90
101
no CT
min
0:33
EtCO2
mmHg
49
30
--
P-P
cmH2O
22.2
FiO2
%
26
18
21
VMe
L/min
25.0
3.0
23.9
1/2
Seuils auto.
Réarmer
Historique
Retour
FiO2
%
21
f CPV
c/min
10
PB sync
cmH2O
5
PH sync
cmH2O
15
T haut
s
1.0
CPV
Masque
ADULTE

3rd Question :

What is the best way to ventilate?

Throughout the years…

- Passive ventilation ?
- Bag Valve Mask ?
- Supraglottic devices?
- Intubation ?
- Continuous Flow insufflation ?

Bobrow et al. Ann Emerg Med 2009

Wong et al. Resuscitation 2010

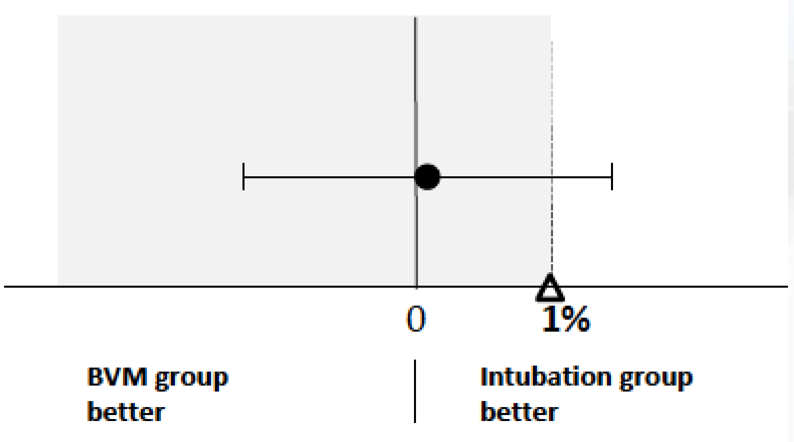
Bertrand et al, Intensive Care Med. 2006

JAMA | Original Investigation

Effect of Bag-Mask Ventilation vs Endotracheal Intubation During Cardiopulmonary Resuscitation on Neurological Outcome After Out-of-Hospital Cardiorespiratory Arrest

A Randomized Clinical Trial

Primary outcome	BMV (N=1018)	ETI (N=1022)	Difference	[95% CI]
Survival with good neurological status at day 28	N= 42 (4.2%)	N= 43 (4.3%)	0.11	[-1.64; 1.87]



Item	BMV group (N=1028)	ETI group (N=1001)	p
BMV or ETI failure – no. (%)	64 (6.3)	26 (2.5)	<0.0001
BMV or ETI difficulty – no. (%)	186 (18.1)	134 (13.4)	0.004
Regurgitation of gastric content	152 (14.9)	79 (7.7)	<0.0001

ETT v/s Mask

P. Jabre, JAMA. 2018;319(8):779-787. doi:10.1001/jama.2018.0156

To intubate or not: ventilation is the question!

BVM

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Table 2: Ventilation parameter values measured during all the 5-minute ventilation tests (n = 280), realized with 140 participants ventilating with two different BVM on an intubated apneic patient.

A. Khoury et al, BMJ Open Respiratory Research, in Revision 2018

3 Questions :

Two answers

Members

American Heart Association. Learn and Live

European Resuscitation Council

Heart & Stroke Foundation. Finding answers. For life.

Australian Resuscitation Council

New Zealand Resuscitation Council

Resuscitation Council of Southern Africa

InterAmerican Heart Foundation

Resuscitation Council of Asia

International Liaison committee on Resuscitation

International Liaison Committee on Resuscitation (ILCOR)

2015

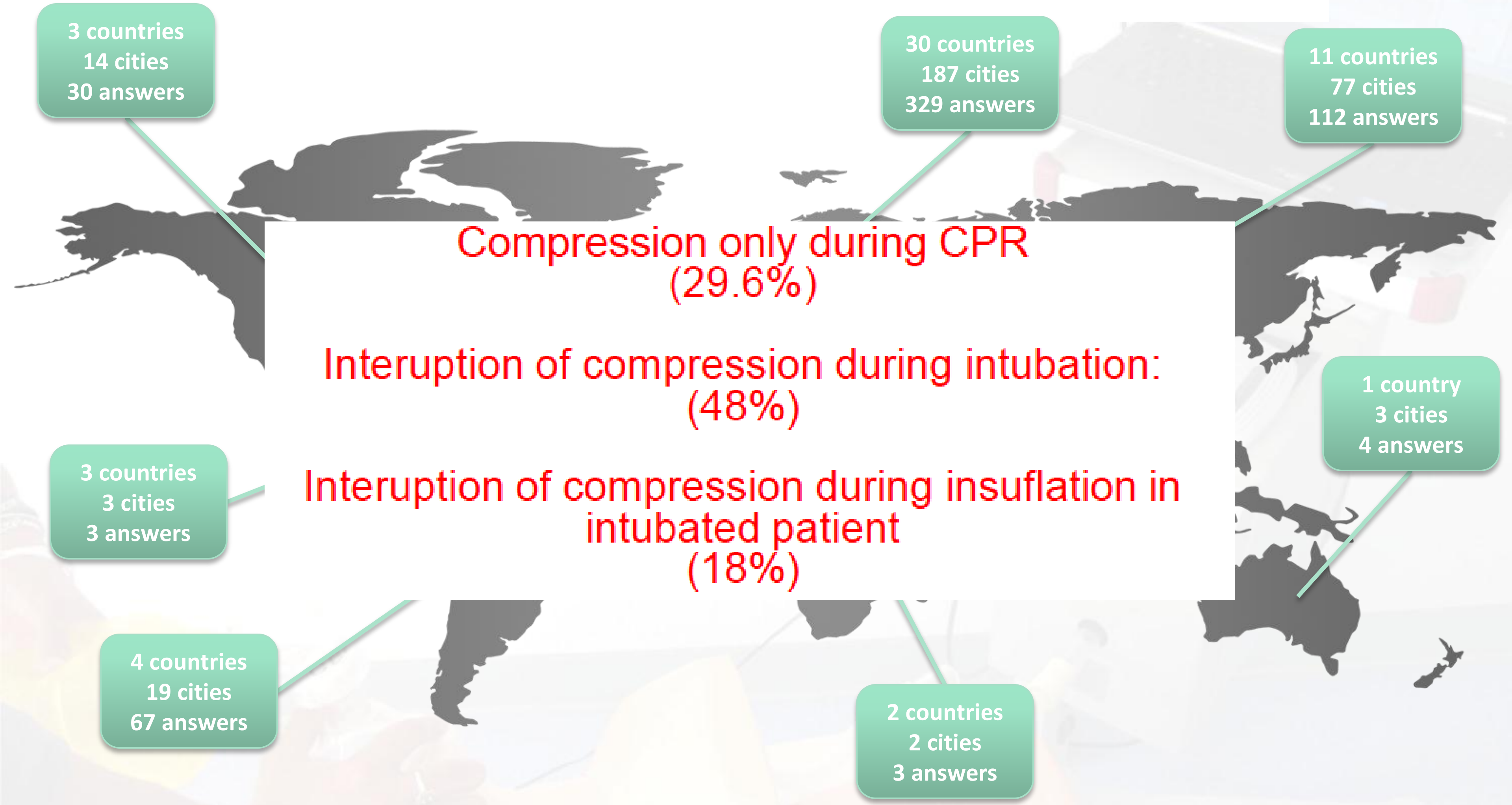
1. There is definitely a need to ventilate

- If BVM >> 30:2
- If ETT >> Continuous

- RR = 8 – 10/ min
- V_T = 400- 600 ml

Practice survey - Ventilation During Out-Of-Hospital Cardio-Pulmonary Resuscitation

Preliminary Report : 1328 questionaries / 545 completed



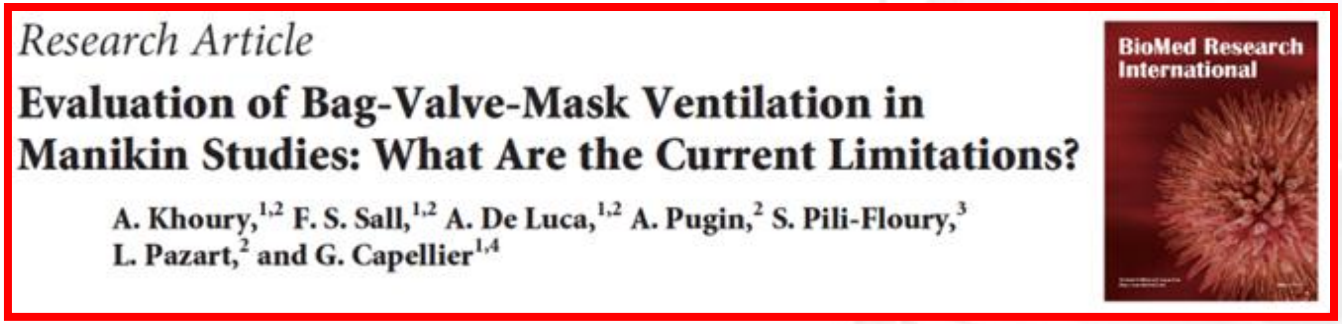
Compression only during CPR
(29.6%)

Interuption of compression during intubation:
(48%)

Interuption of compression during insuflation in intubated patient
(18%)

R Cordioli, L Suppan, F Templier, D Savary, S Delisle, A Khoury, L Brochard and JC Richard

Which factor leads to inadequate ventilation?


Research Article

Evaluation of Bag-Valve-Mask Ventilation in Manikin Studies: What Are the Current Limitations?

A. Khoury,[1,2] F. S. Sall,[1,2] A. De Luca,[1,2] A. Pugin,[2] S. Pili-Floury,[3] L. Pazart,[2] and G. Capellier[1,4]

There is no monitoring during manual ventilation

- No measurement of the ventilatory parameters
- No evaluation of the patient clinical needs
- No feedback of ventilation efficiency

2. **We don't know what we are doing!**

Anaesthesia
Journal of the Association of Anaesthetists of Great Britain and Ireland

Performance of manual ventilation: how to define its efficiency in bench studies? A review of the literature*

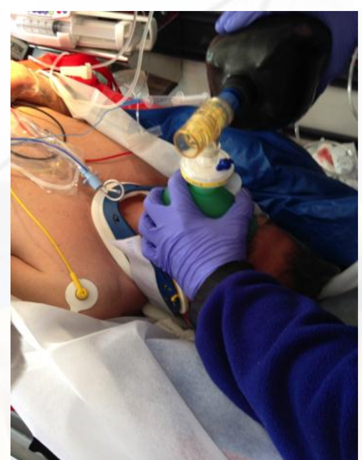
A Khoury,[1] A De Luca,[2] FS Sall,[3] L Pazart,[4] and G Capellier[5]

Anaesthesia. 2015 Aug; 70(8): 985–992.
Published online 2015 May 21. doi: 10.1111/anae.13097

Manual Ventilation is difficult to realize in stressful conditions

→Efficiency varying from 0 to 38% according to studies






Khoury, Anaesthesia 2015


HELP!

Monitoring and feedback System

→Provide a real-time feedback of ventilation efficiency according to the patient characteristics and the clinical situation

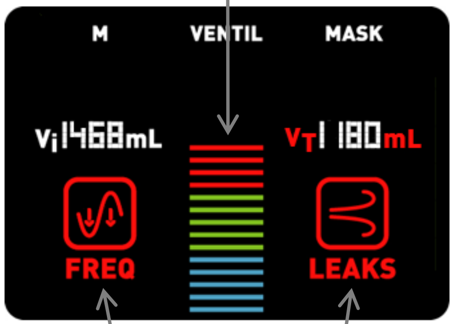
CHRU Besançon
centre hospitalier régional universitaire

Monitoring and feedback System

Screen

Timer bars to provide adequate ventilation frequency

Bar-graph for tidal volume adequacy



Insufflated and tidal volume display

Interface (On/Off ; selection of ventilation modes and patient profile)

Alarm signals (high frequencies, leakage…)

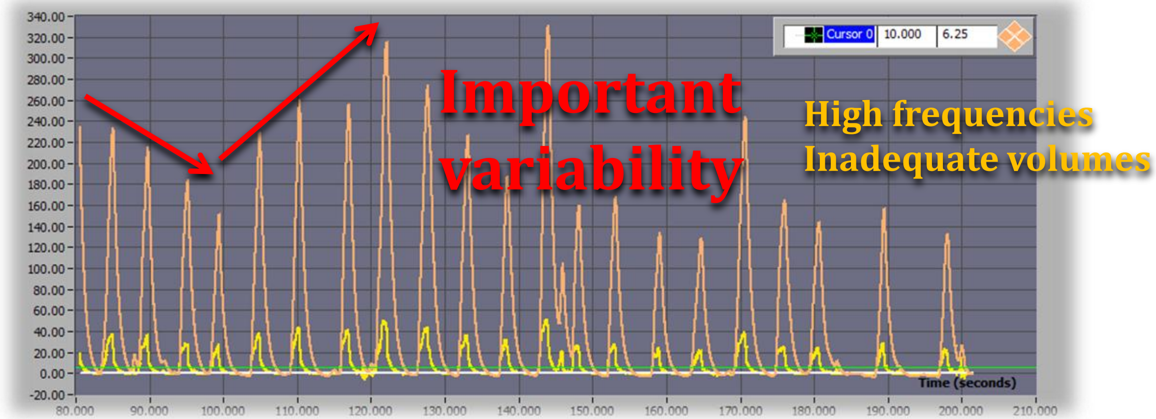
CHRU Besançon
centre hospitalier régional universitaire

Monitoring and feedback System

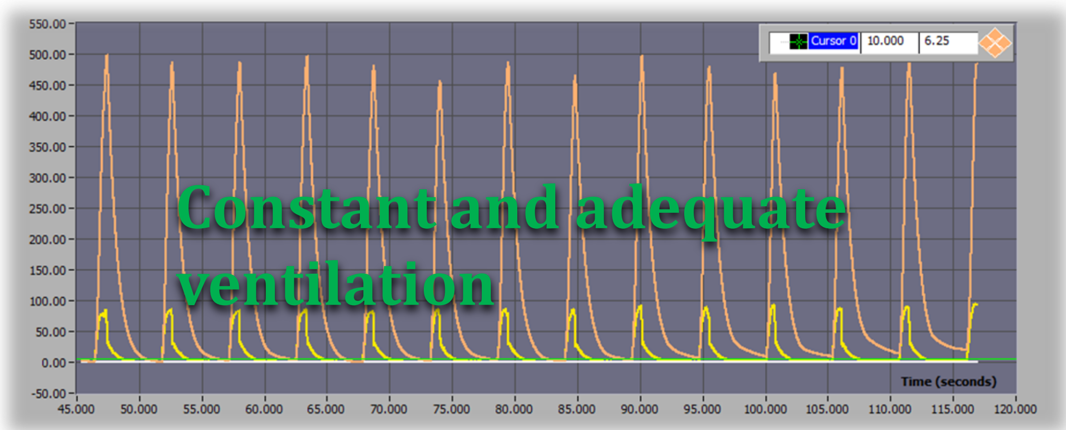
CHRU Besançon
centre hospitalier régional universitaire

Monitoring and feedback System

Ventilation without



Ventilation with

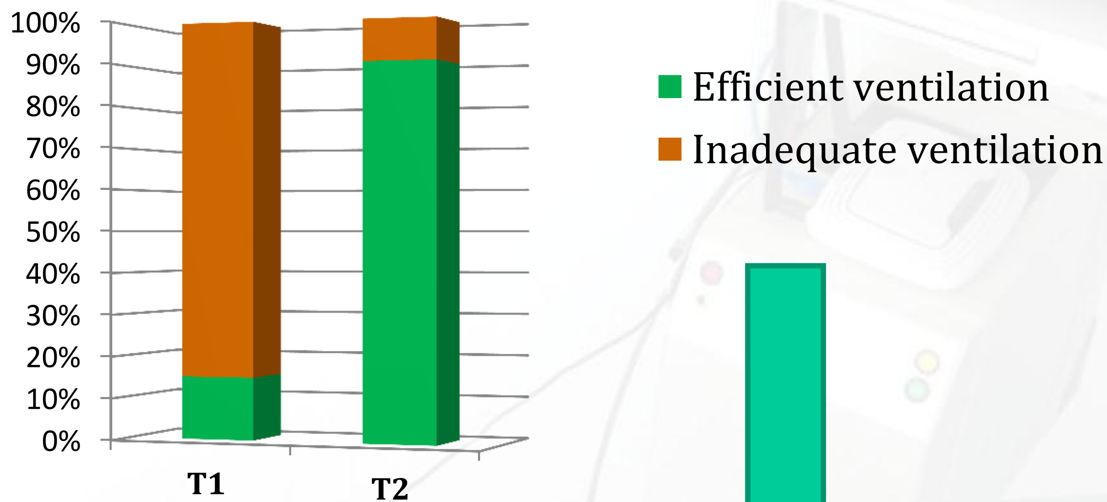


Monitoring and feedback System

Randomized control trial

40 healthcare providers

(anesthetists, emergency physicians and paramedics)



From 15% to 90% of efficient ventilation

Submitted

Is this the future ?

Mechanical Ventilation During Cardiopulmonary Resuscitation With Intermittent Positive-Pressure Ventilation, Bi-level Ventilation, or Chest Compression Synchronized Ventilation (CCSV) in a Pig Model*

Kill, Crit Care Med 2014; 42:e89–e95

- During CC, CCSV mode leads to ventilations with a respiratory rate of 100 per minute
- Synchronized with the start of each chest compression for a duration of only 205ms and inspiration being stopped before the decompression period begins.

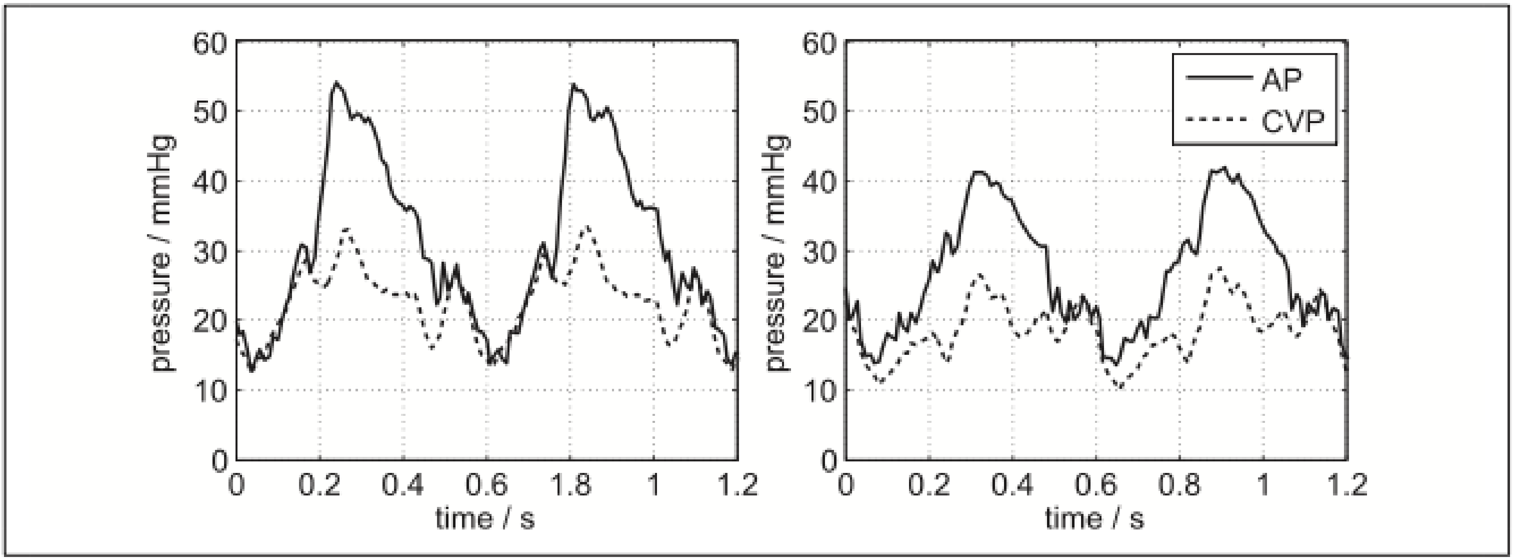


Figure 2. Arterial pressure (AP, *continuous line*) and central venous pressure (CVP, *dashed line*) curves with chest compression synchronized ventilation (left-hand side) and no ventilation (right-hand side).

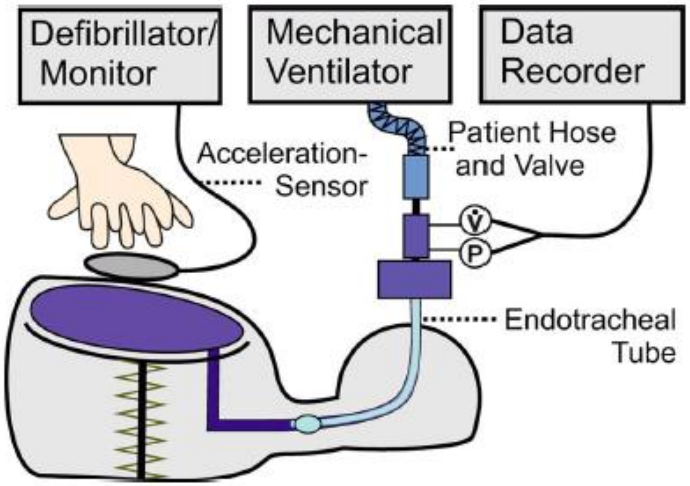
Adv Ther (2017) 34:2333–2344 ***Kill, PLOS ONE May 26, 2015***

Adv Ther (2017) 34:2333–2344
DOI 10.1007/s12325-017-0615-7

CrossMark

ORIGINAL RESEARCH

Mechanical Ventilation During Resuscitation: How Manual Chest Compressions Affect a Ventilator's Function



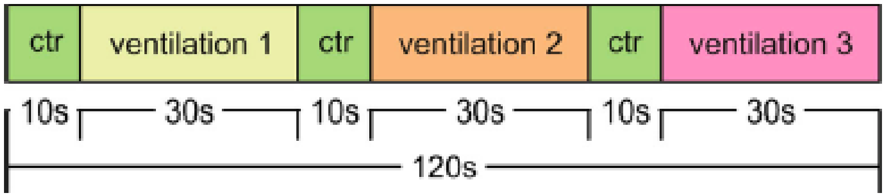


Fig. 2 Experimental procedure. The order of ventilation modes (IPPV, BiLevel, CCSV) was randomized in a crossover design with control phases (ctr) at the beginning and in between

T. Speer, Adv Ther (2017) 34:2333–2344

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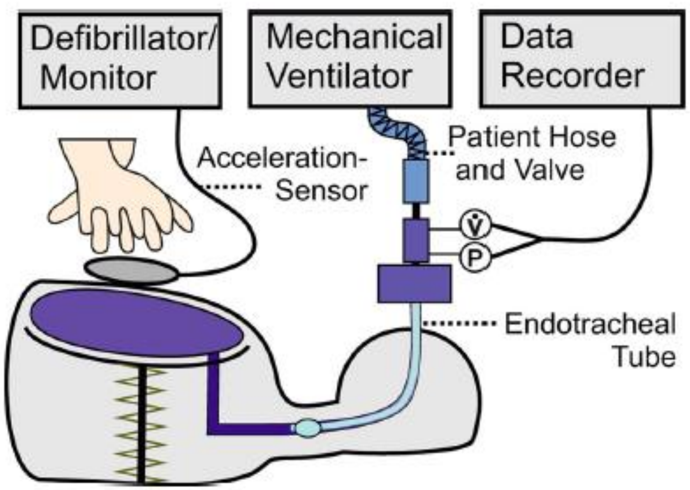

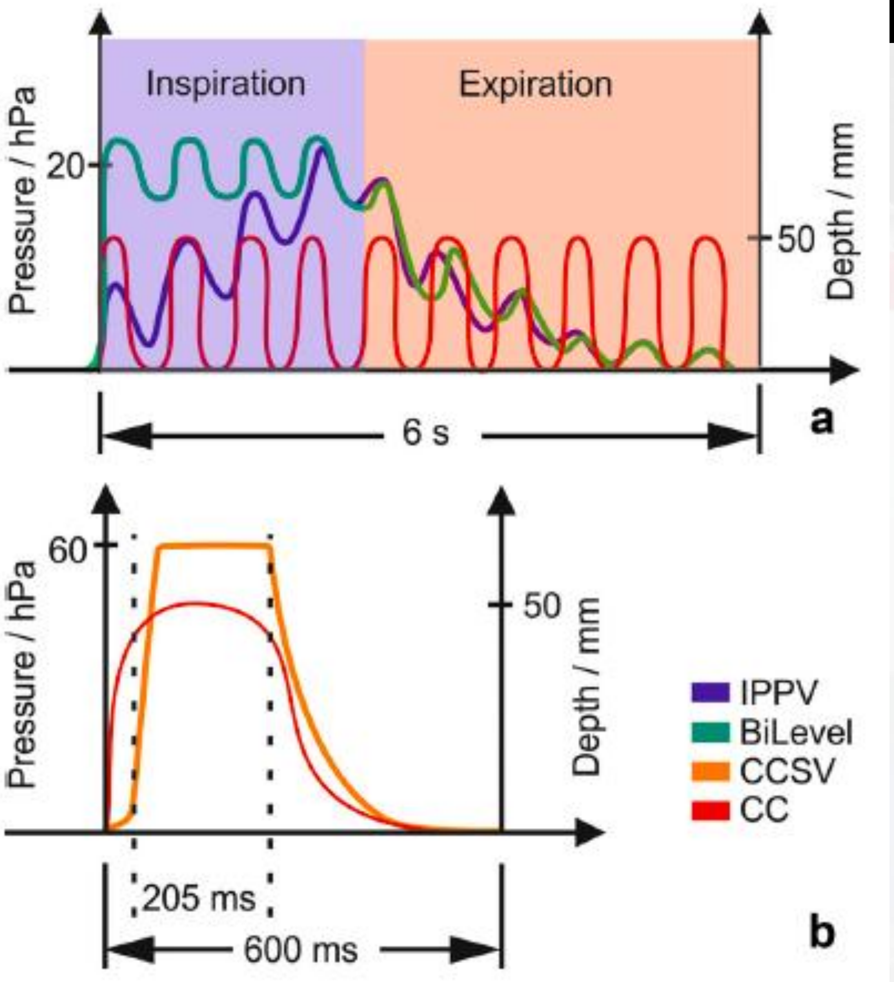

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Conclusion

- Yes we need to ventilate
- We need to adapt compressions to ventilation

- Monitoring and feedback are needed to assess the quality of Ventilation and thus improve survival

Thank you for your attention

8-12 September 2018