Review / Update

Estimated Cost of Inadvertent Hyperventilation on Intensive Care Departments

Inadvertent Hyperventilation (IH) (which is the delivery of an excessive minute volume), during CPR or respiratory arrest, has been shown to be very common and to have severe detrimental effects on patient hemodynamics[1] as well as the associated risks of gastric insufflation and pulmonary aspiration of stomach contents. In traumatic brain injury IH also contributes to increased brain ischemia [2].

Current International Resuscitation Guidelines[3] clearly indicate that ventilations should be provided in a slow, controlled, manner with tidal volumes being limited to 6 – 7 ml/kg and ventilation rates to be in the 10 – 12 breaths per minute in adults. However, studies have shown ventilation rates to be 2 - 3 times this recommended rate[1] [4] with tidal volumes and airway pressures being excessive and inspiratory times being too short. While the physiological effects on these patients have been evaluated the additional cost of these negative actions on patient care in the hospital has not been clearly defined.

Pulmonary aspiration of stomach contents during CPR is, not surprisingly, very high. Felegi et al[5] in their 1996 study showed pulmonary aspiration rates as high as 33% in non-survivors of cardiac arrest. Lawes and Basket[6] reported in the Intensive Care medicine journal that "the incidence of pulmonary aspiration in a group of patients who did not respond to cardiopulmonary resuscitation (CPR) was assessed at autopsy and found to be 29%. This figure is undoubtedly an underestimate of the total problem. In survivors, any aspiration of stomach contents will have seriously detrimental effects morbidity and mortality.

Another issue related to inadvertent hyperventilation is barotrauma, due to excessive tidal volume delivery and breath stacking, which may require post arrest treatment and intensive care stays. Emergency tracheal intubation is also not without significant risk.

When requiring ventilation in the ICU, patients also run the risk of ventilator associated pneumonia (VAP). Hunter, in his paper in the BMJ[7] stated: "Ventilator associated pneumonia is the most common healthcare associated infection in intensive care". "The condition is associated with increased morbidity, mortality, length of stay, and costs". VAP accounts for about half of all antibiotics given in the ICU. It occurs in 9-27% of mechanically ventilated patients. The condition is associated with increased ICU and hospital stay and has an estimated attributable mortality of 9%.

In the HCNA Series[8] it is stated that there are "ten conditions that use the greatest number of bed-days" in the ICU, one of which is inhalation pneumonitis (gastrointestinal contents)". These ten conditions made up 32.8% of ICU bed-days with an average length of stay 5.02 days. Nolan et al[9] stated in their article in anesthesia that, in the UK:
"Mechanically ventilated survivors of cardiac arrest accounted for 24,132 (5.8%) of all admissions."

Tan SS. et al[10] showed daily ICU costs in four European Countries to be in the range of €1168 – €2025 (£1000 - £1800) per day. In North America these average daily costs for a ventilated patient are estimated to be $5,500 per day[10]. Therefore, the per-patient cost of treating, what is a potentially avoidable complication of cardio pulmonary resuscitation, is significant and estimated to be in the €5,800 - €10,000 (£5,000 – 9,000) range in Europe. In North America this cost is estimated to be $27,500[11].

These figures equate to an average annual cost burden (of out of hospital cardiac arrest and the issues related to Inadvertent Hyperventilation) on the various country healthcare systems of:

	Annual OHCA	Annual ICU cost
UK	60,000[12]	£ 168,924,000
Europe	275,000[13]	€ 635,250,000
USA	359,400[14]	$ 3,261,555,000

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Conclusions

Inadvertent hyperventilation needs to be removed from the CPR equation to reduce both morbidity and mortality in cardiac arrest. The added cost of treating cardiac arrest survivors who have been respiratory compromised to the point of requiring ICU admission due to inadvertent hyperventilation is significant. Improved methods of providing controlled ventilation (such as Automatic Transport Ventilators and flow controlling manual resuscitators need to be routinely employed during CPR. Technology based solutions can assist in reducing this cost burden on healthcare systems (with minimal increased expenditure on devices and training) to provide controlled ventilation.

References:

[1] Aufderheide et al. Hyperventilation Induced Hypotension During CPR Circulation April 27, 2004

[2] Guidelines for the management of Severe Brain Injury. BrainTrauma Foundation, American College of Neurosurgeons 1995

[3] Nolan JP et al. European Resuscitation Council Guidelines for Resuscitation 2010. Resuscitation 81 (2010)1219 - 1276

[4] Maertens VL et al Patients with cardiac arrest ventilated two times faster than guidelines recommended. Resuscitation 84 (2013) 921-926

[5] Felegi WB, et al Gastric trauma and pulmonary aspiration at autopsy after CPR. Acad Emerg Med 1996;3:441

[6] Lawes EG, Baskett PJF. Pulmonary aspiration During unsuccessful CPR Intensive Care Medicine 19879, Volume 13, Issue 6, pp 379-382

[7] Hunter JD, Ventilator associated pneumonia BMJ 2012;344:e3325

[8] Cronin E, et al: Adult Critical Care - HCNA_Series3_D2.3d – 10/1/7 1

[9] Nolan JP, et al: Outcome following admission to UK Intensive Care Units after cardiac arrest: a secondary analysis of the ICNARC Case Mix Programme Database. Anaesthesia. 2007 Dec;62(12):1207-16.

[10] Tan SS, et al. Direct Cost Analysis of Intensive Care Unit Stay in Four European Countries: Applying a standardized Costing Methodology. Value in Health 15 (2012) 81 – 86

[11] Dasta JF, et al: Daily cost of an intensive care unit day: the contribution of mechanical ventilation. Crit Care Med. Jun;33(6):1266-71.

[12] Malhotra A Improving the UK's performance on urvival after cardiac arrest BMJ 2013;347:f4800

[13] Attwod, C. et al: Incidence of EMS-treated out-of-hospital cardiac arrest in Europe. Resuscitation. 2005 Oct;67(1):75-80.

[14] AHA Heart Disease and Stroke Statistics 2013 Update online on December 12, 2012.

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