Brain Cooling in Traumatic Brain Injury and Stroke

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- Therapeutic temperature reduction after acute cerebral insults - evidence and practice - normothermia, hypothermia
- Terminology and scope
- Systemic versus brain cooling – why brain cooling?
- Methods of non-invasive brain cooling – pros and cons
- Temperature measurement
- Effect of therapeutic brain cooling on temperature – clinical studies
- Future directions

Terminology and scope

- Selective brain cooling vs therapeutic brain cooling – terminology
- Therapeutic brain cooling methods
  - Invasive
    - neuroprotection during surgery e.g. antegrade cerebral perfusion for aortic arch surgery
  - Non-invasive
    - Nasal/pharyngeal cooling
    - External head cooling
- Therapeutic brain cooling – acute cerebral insults - global and focal – normothermia, hypothermia

Evidence for therapeutic temperature reduction in acute global cerebral insults

- Comatose survivors of cardiac arrest (VF), neonatal hypoxic ischaemic injury
  - therapeutic hypothermia reduces mortality, improves functional outcome

  (Arrich et al. *Cochrane Database Syst Rev* 2012;9:CD004128; Jacobs et al. *Cochrane Database Syst Rev* 2013;1:CD00331)

- In these conditions therapeutic hypothermia is recommended as part of standard care

Evidence for therapeutic temperature reduction in acute focal cerebral insults

Traumatic brain injury (TBI), stroke

- **experimental evidence**
  - improved outcome with normothermia and hypothermia
  - multifactorial neuroprotective effects (early)
  - prevention and reduction of secondary insults

  (Dietrich & Bramlett *Prog Brain Res* 2007;162:201-17; van der Worp et al. *Brain* 2007;130:3063-74)

- **human evidence**
  - increased temperature is common and associated with worse outcome - death and disability (e.g. Greer et al. 2008 Stroke 39:3029-35)
  - insufficient evidence that therapeutic temperature modulation - normothermia or hypothermia - improves outcome

  (Saxena et al. 2008; Sydenham et al. 2009; den Hertog et al. 2009 - *Cochrane Database Syst Rev*; Lakhan & Pamplona *Stroke Res Treat* 2012:295906; Georgiou & Manara *Br J Anaesth* 2013;110:357-67)
  - normothermia is standard practice +/- hypothermia for refractory raised intracranial pressure

  (Johnston et al. *Resuscitation* 2006;70:254-62; Thompson et al. *J Neurosci Nurs* 2007;39:151-62)
  - shivering

Systemic cooling versus brain cooling – why brain cooling?

Systemic methods – drugs (e.g. acetaminophen), cooling blankets/pads, intravenous cooling catheters – side effects

Brain cooling – nasal/pharyngeal cooling and external head cooling – rationale

- Brain cooling has fewer side-effects than systemic hypothermia e.g. infection – some studies use body warming (Feigin et al. *J Clin Neurosci* 2002;9:502-7; Gluckman et al. *Lancet*;365:663-70; Harris et al. *J Neurosurg* 2009;110:1256-64)
- Brain rather than body temperature is important in cerebral protection (Busto et al. *J Cereb Blood Flow Metab* 1987;7:729-38; Busto et al. *Crit Care Med* 1989;20:1113-4)
- Preferential cooling of cortices (external cooling) ?of benefit (Wityk *Crit Care Med* 1994;8:1278-93)
- Little evidence in humans (Harris et al. *HTA* 2012;16;1-175)

Methods of non-invasive brain cooling – pros and cons

Nasal/pharyngeal cooling – induce heat loss from the upper airways by

- convection +/- evaporation e.g. nasal gas flow, nasal lavage
- conduction e.g. nasal or pharyngeal balloons

External head cooling – induce heat loss through the skull by

- convection +/- evaporation e.g. fanning,
- conduction e.g. circulating liquid cooling helmet (active), ice packs/frozen gel helmet (passive)

Pros and cons

Temperature

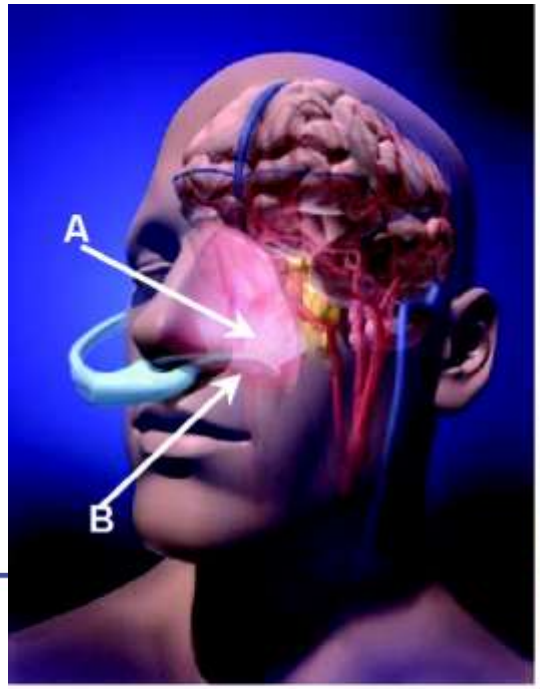
- Temperature measurement sites
  - Intracranial
  - Tympanic
  - Magnetic resonance spectroscopy
  - Core body – PA, oesophagus, bladder, rectum – best proxy
- Effectiveness of brain cooling in reducing temperature (Harris et al. *HTA* 2012;16(45)1-175)

Summary of average temperature reduction with therapeutic cranial cooling

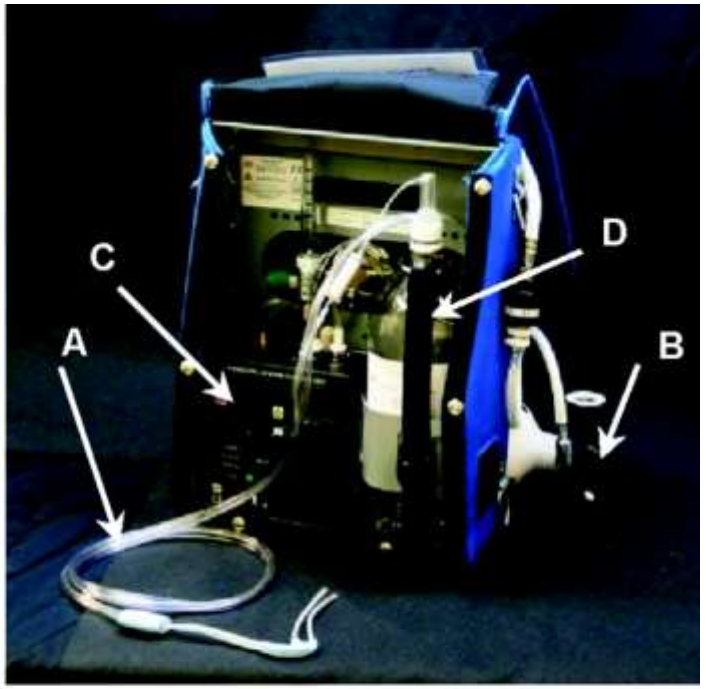
(studies reporting temperature reduction achieved)

Head cooling method	Cooling duration	Intracranial temp reduction (total cooled pts)	Core body temp reduction (total cooled pts)
Rhinochill (upper airways) (Andreas 2008, Busch 2010, Abou-Chebl 2011)	60 mins	**1.4 °C** (n=11)	**1.1–1.3 °C*** (n=106)
Quickcool nasal balloons (Springborg et al 2013)	72 hr	**~1 °C** (n=6)	**~1 °C** (n=9)
Nasal airflow + head fanning (Harris 2007)	30 mins	**0.41 °C** (n=12)	**0.32 °C** (n=12)
Gel head and neck (Sovika) (Poli et al 2013)	~50 mins	**0.36 °C** (n=11)	**0.25 °C** (n=11)
Circulating liquid head and neck (Wang 2004, Harris 2009, Gaida 2008, TraumaTec Neuro ICU study/Miller 2009)	1–24 hr	**1–2 °C** (n=34)	**0.8 °C** (n=6)

* includes mean and median data, all other temperatures are mean reductions



A: coolant spray
B: nasal catheter

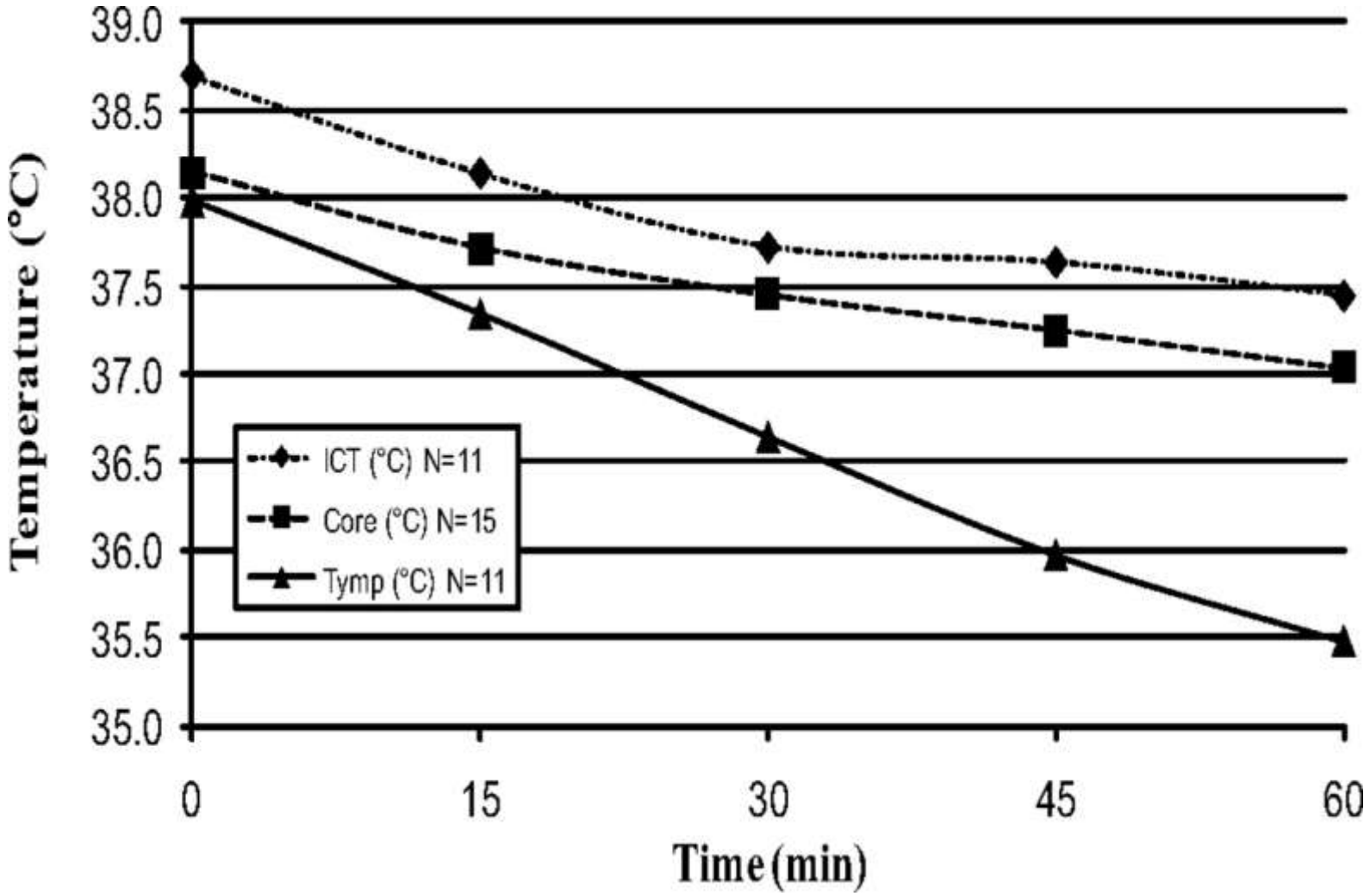


A: nasal catheter
B: oxygen tank
C: control unit
D: coolant bottle

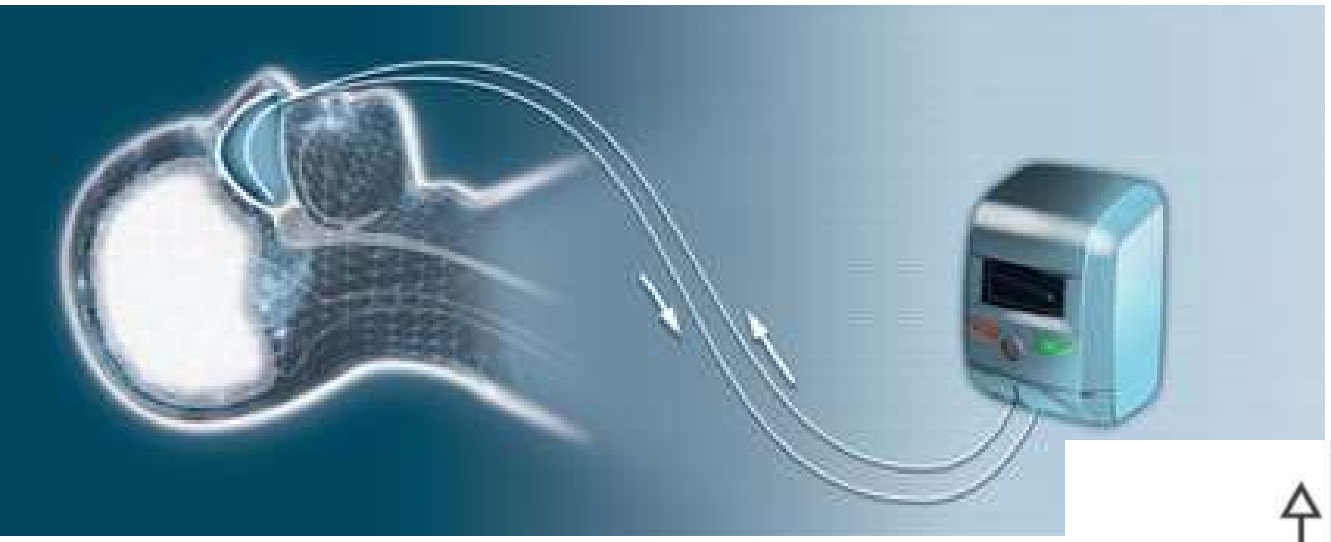
Rhinochill Intranasal Cooling Device

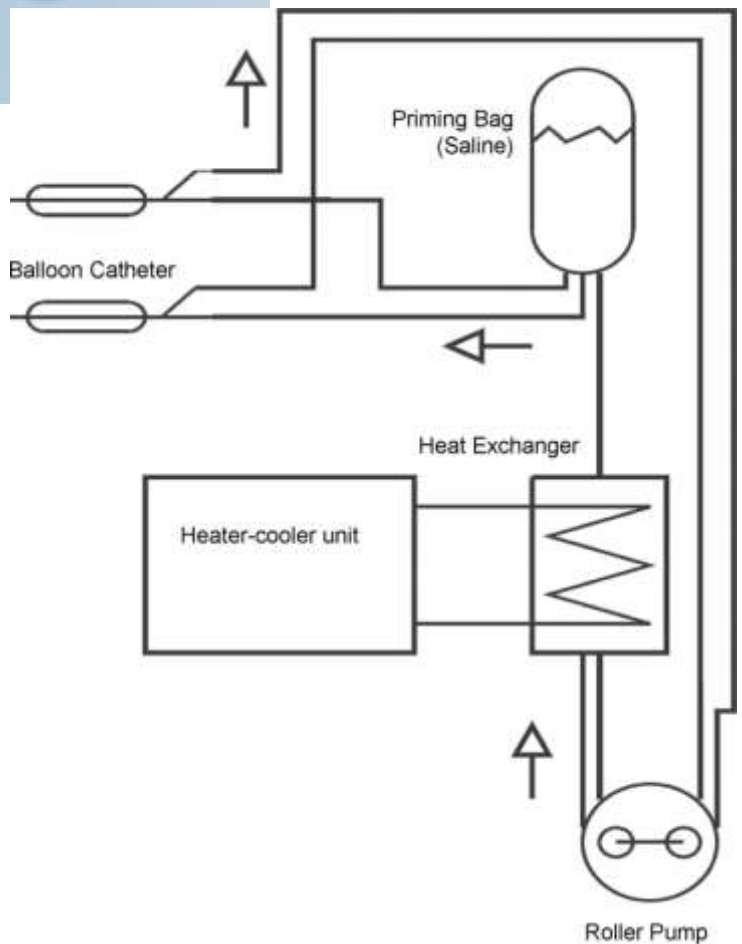
Benechill, Inc. USA

Mean temperature reductions during the 1-hour RhinoChill induction



Mean temperature reductions during 1-hour cooling with RhinoChill
ICT = intracranial temperature (Abou-Chebl et al. *Stroke* 2011;42:2164-9)





QuickCool nasal balloons

QuickCool AB, Lund

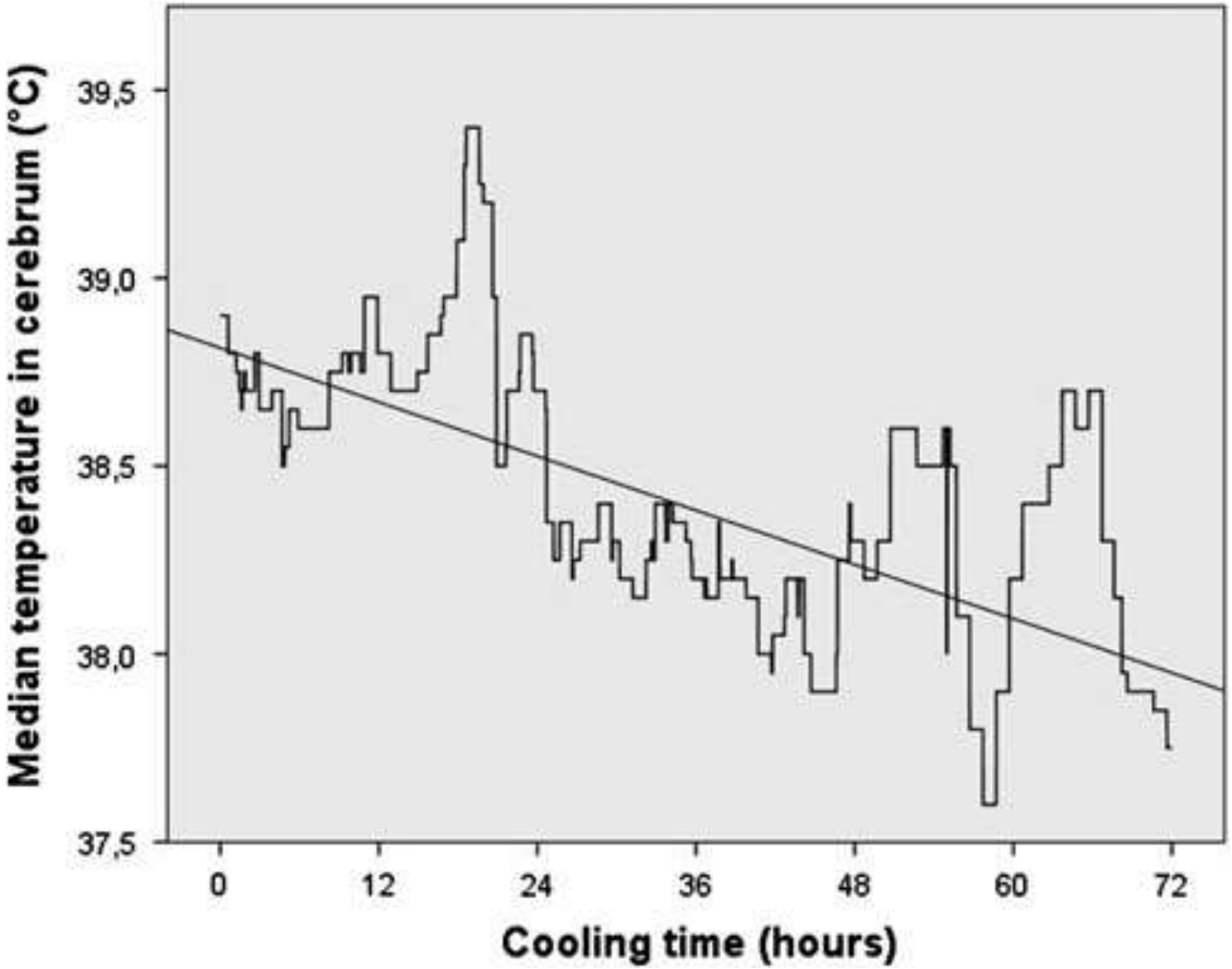
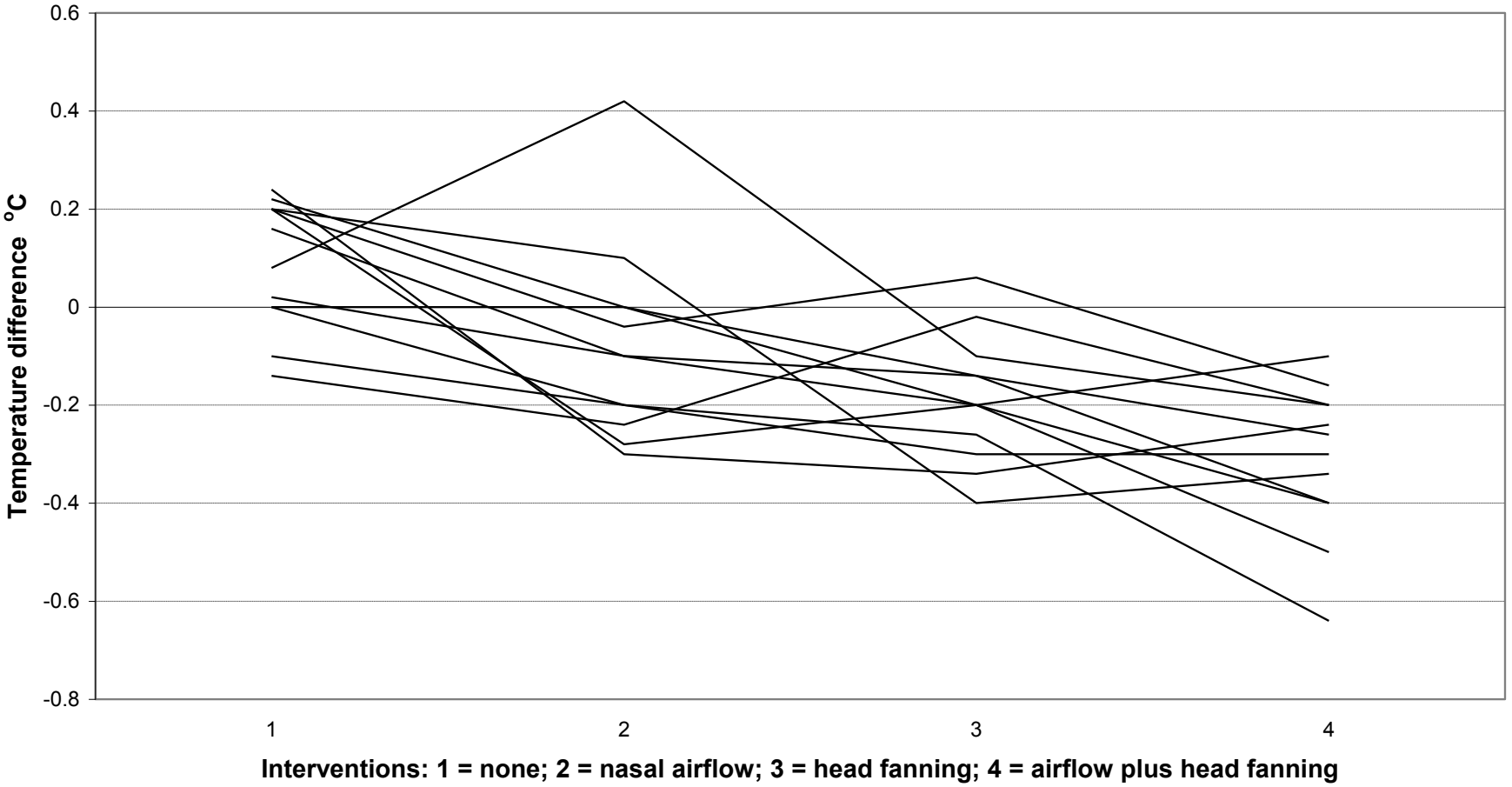


Fig. 2 Median temperature in the cerebrum in the first 72 h of cooling. As indicated by the linear regression line a temperature level of 37°C was not reached within 72 h of cooling ($y = -0.012x + 38.814$, $R2 = 0.111$, $p < 0.0001$) (n=6)
Springborg et al. *Neurocrit Care* 2013; 18(3):400-5



12 pts – traumatic brain injury or subarachnoid haemorrhage

Intracranial temperature reduction compared to baseline with:

1. no intervention
2. nasal airflow - twice minute volume (≤24 L) + 20ppm NO
3. bilateral head fanning (ambient air approximately 8 m s^{-1})
4. airflow plus fanning

(Harris et al. *Br J Anaesth* 2007;98:93-9)

MedCool Device

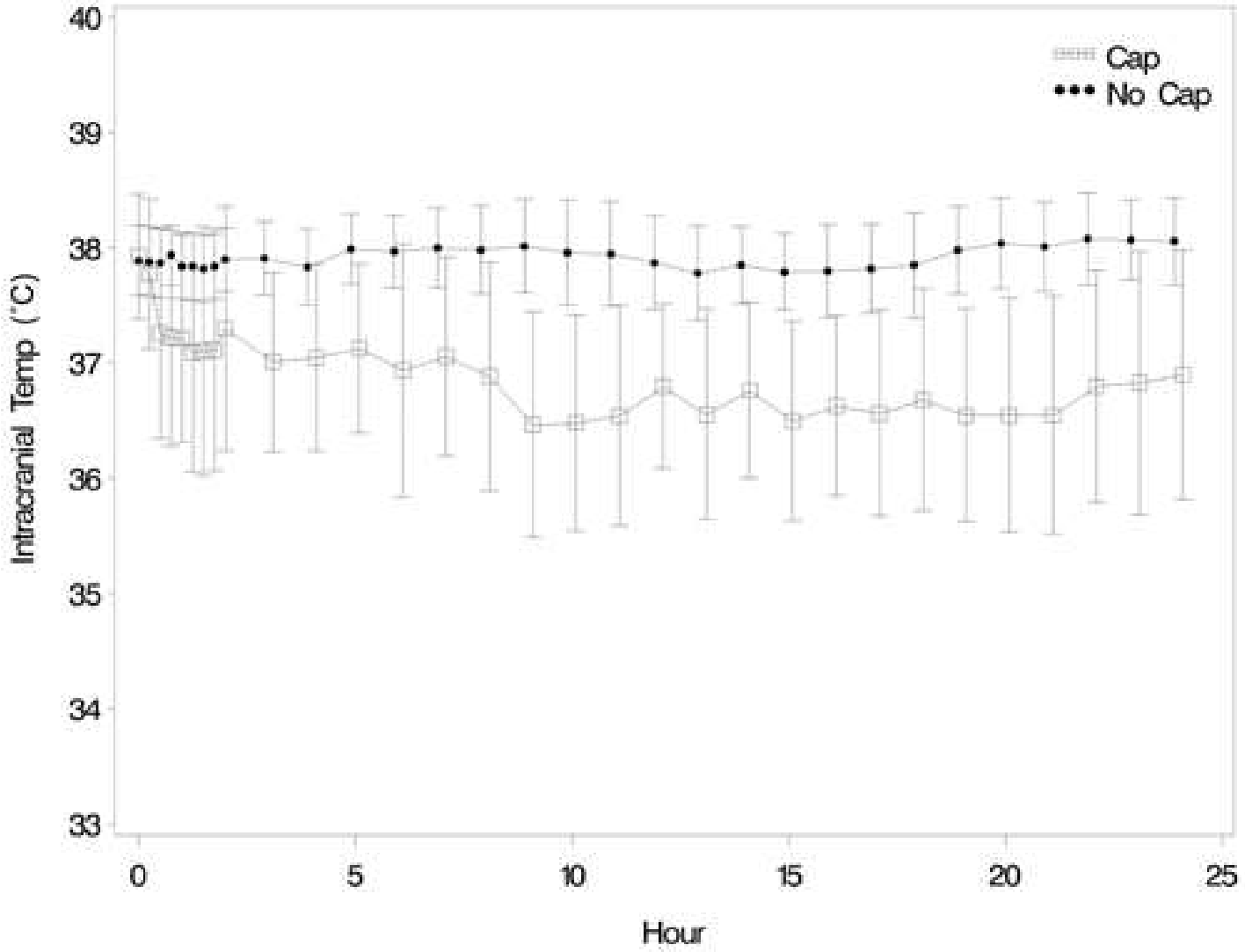
(Wandaller et al. *Am J Emerg Med* 2009;27:460-5)

Forced convective device - soft, fabric helmet

(Wass et al. *J Cardiothorac Vasc Anesth* 2013;27:288-291)

CoolSystem Discrete Cerebral Hypothermia Device

(Harris et al. *J Neurosurg* 2009;110:1256-64)

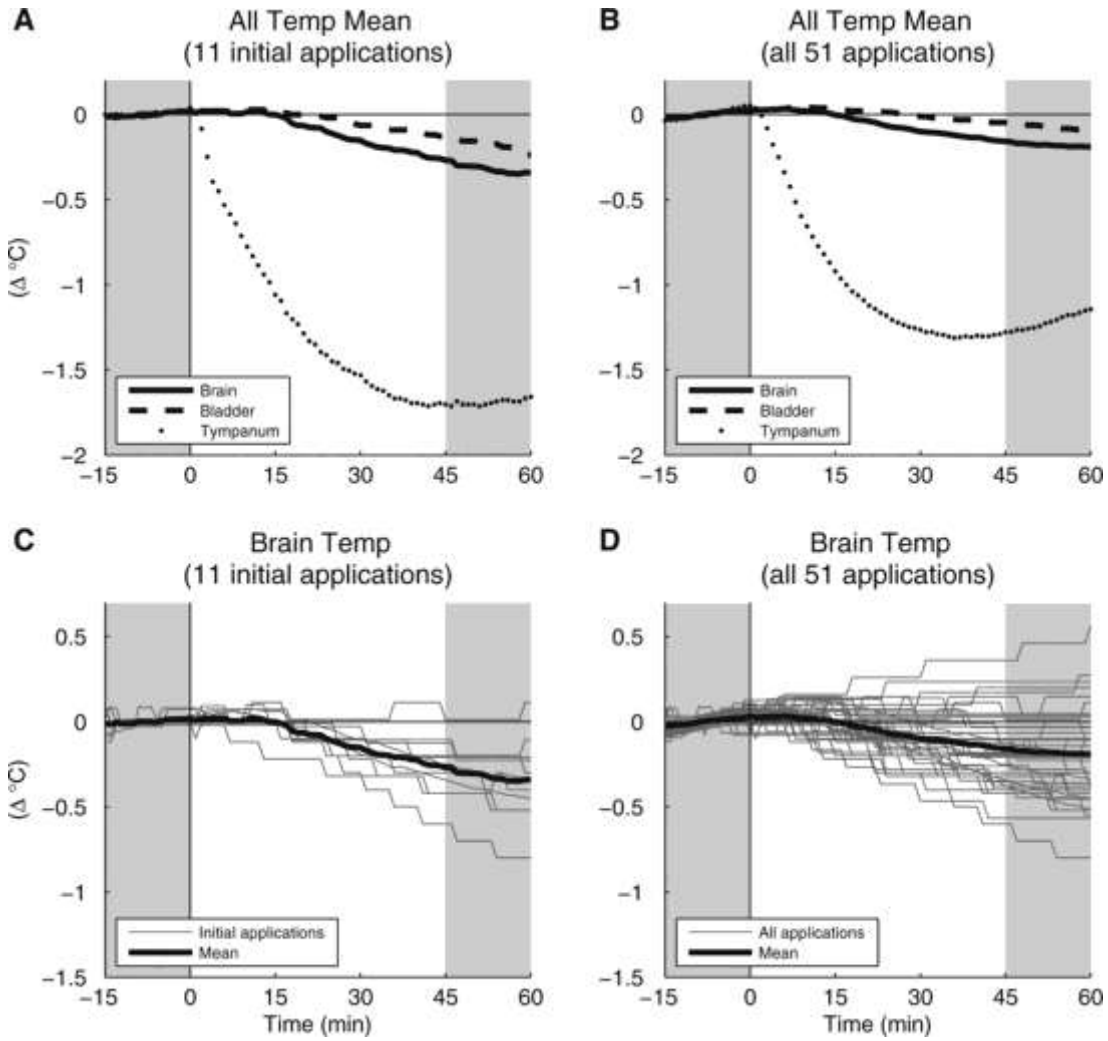


12 pts – traumatic brain injury – 12 head cooled, 13 controls
Mean intracranial temperatures in cooled (cap) vs not cooled (no cap)
After 24 hours, cooled group intracranial temperature 1.2°C lower than controls
(Harris et al. *J Neurosurg* 2009 110;1256-64)

Sovika head and neck cooling device (Sovika GmbH)

(Poli et al. *Stroke* 2013;44:708-13)

Brain, bladder, and tympanic temperatures – stroke patients



(Poli et al. *Stroke* 2013;44:708-13)

Future directions

- Non-invasive methods of measuring intracranial temperature – continuous measurement
- Device development
- Higher quality studies – temp reporting, outcome
  - complications of cranial cooling vs systemic cooling
  - cranial cooling to reduce intracranial pressure
- Standardardised terminology for therapeutic cranial cooling and methods

Thank you

Systematic review of head cooling in adults after traumatic brain injury and stroke

Harris, Andrews, Murray, Forbes, Moseley

Health Technology Assessment 2012;16(45):1-175

can be downloaded without charge from:

www.hta.ac.uk/1777

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