Model-based Noninvasive Intracranial Pressure Estimation for Hydrocephalus Patients

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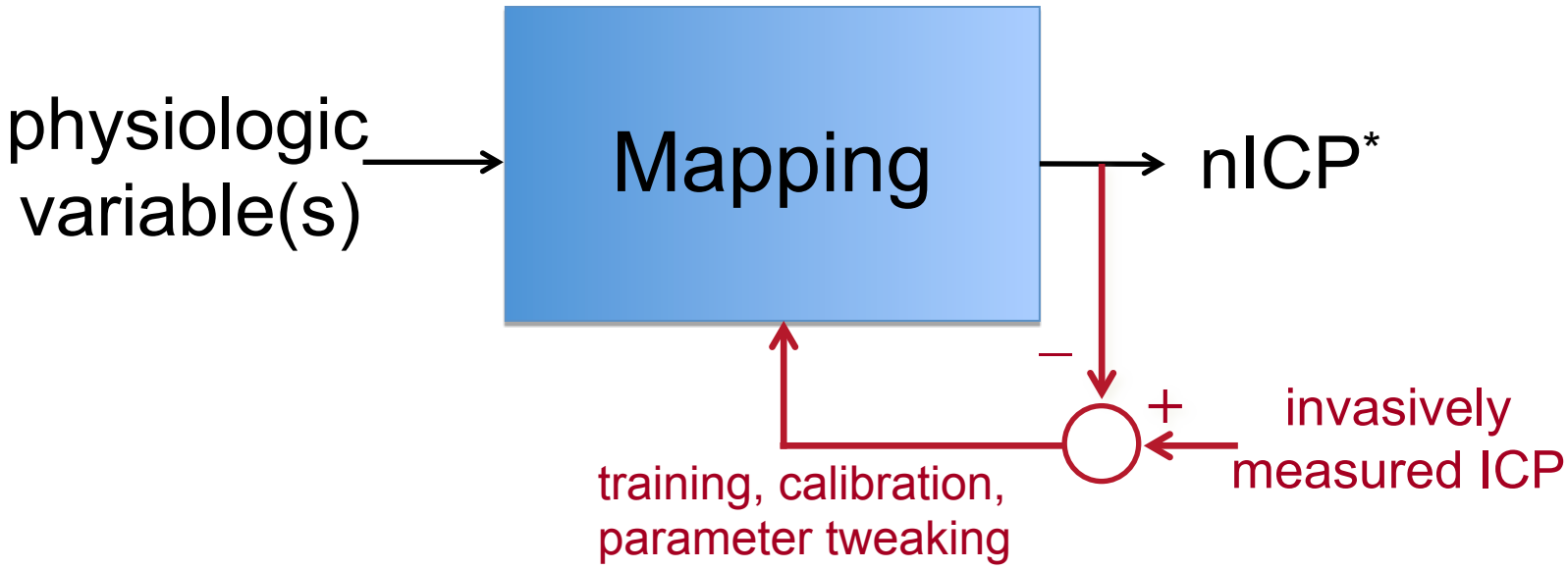
Noninvasive Assessment of ICP

Proposed modalities

Ultrasound time-of-flight, visual evoked potentials, tympanic membrane displacement, MRI features, arterial blood pressure (ABP), cerebral/ophthalmic artery blood flow velocity

nICP: noninvasive ICP estimate

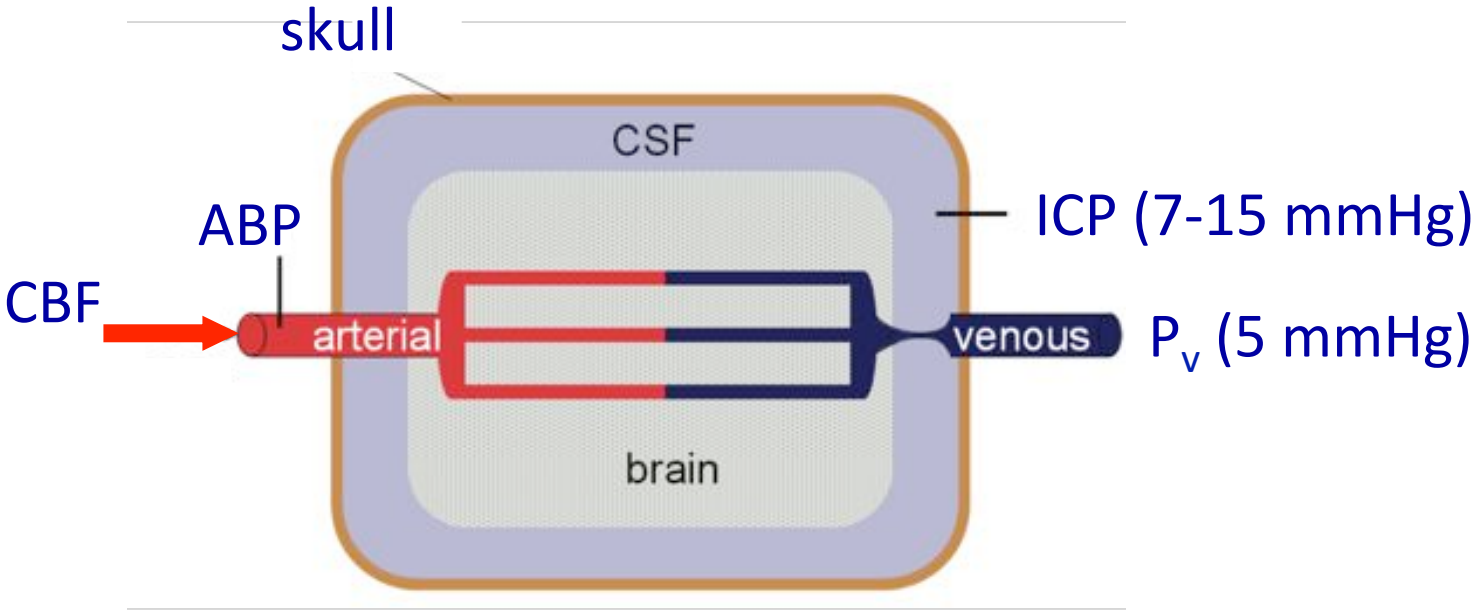
Noninvasive Assessment of ICP



- Training-based methods require *invasively* measured ICP
- Estimation performance strongly depends on *richness of underlying training set*

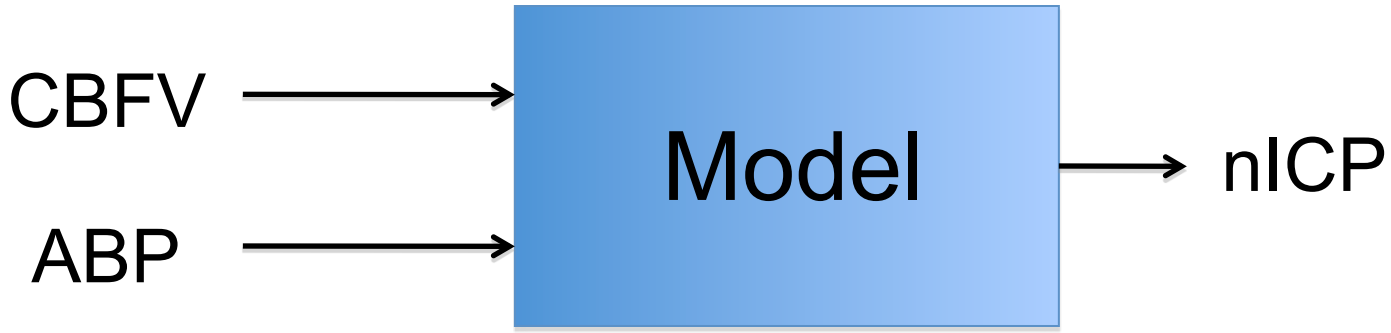
* nICP: noninvasive ICP estimate

Compartmental View



- ABP – ICP = cerebral perfusion pressure (CPP)
- Cerebral blood flow (CBF) is driven by ABP – ICP

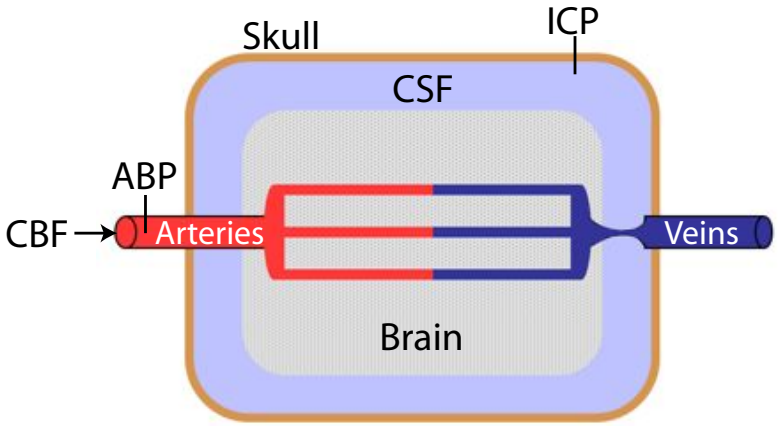
Model-Based ICP Estimation

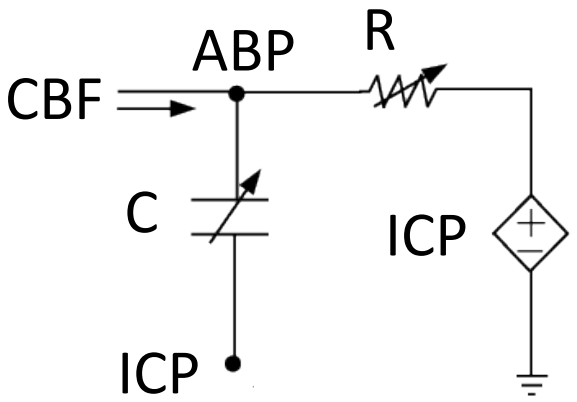


Mechanistic model
of cerebrovascular function

- Small number of interpretable parameters
- Identifiable in real time
- Parameter estimates robust to noise in data

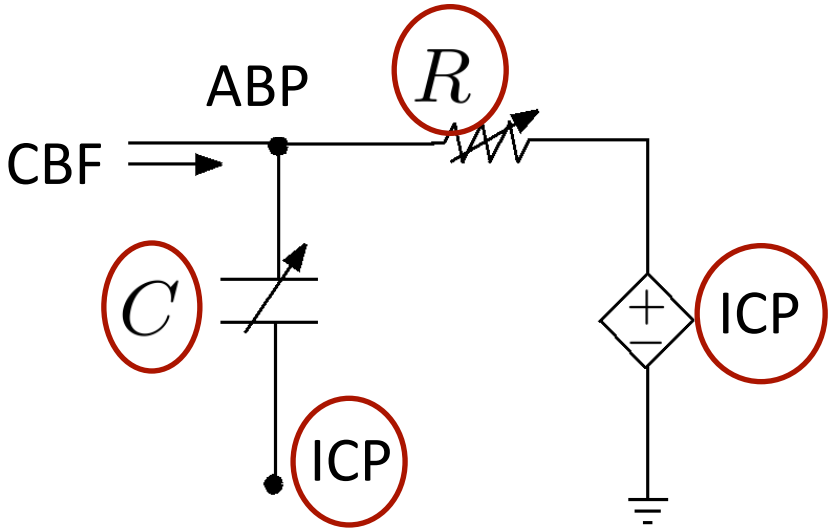
Cerebrovascular Physiology





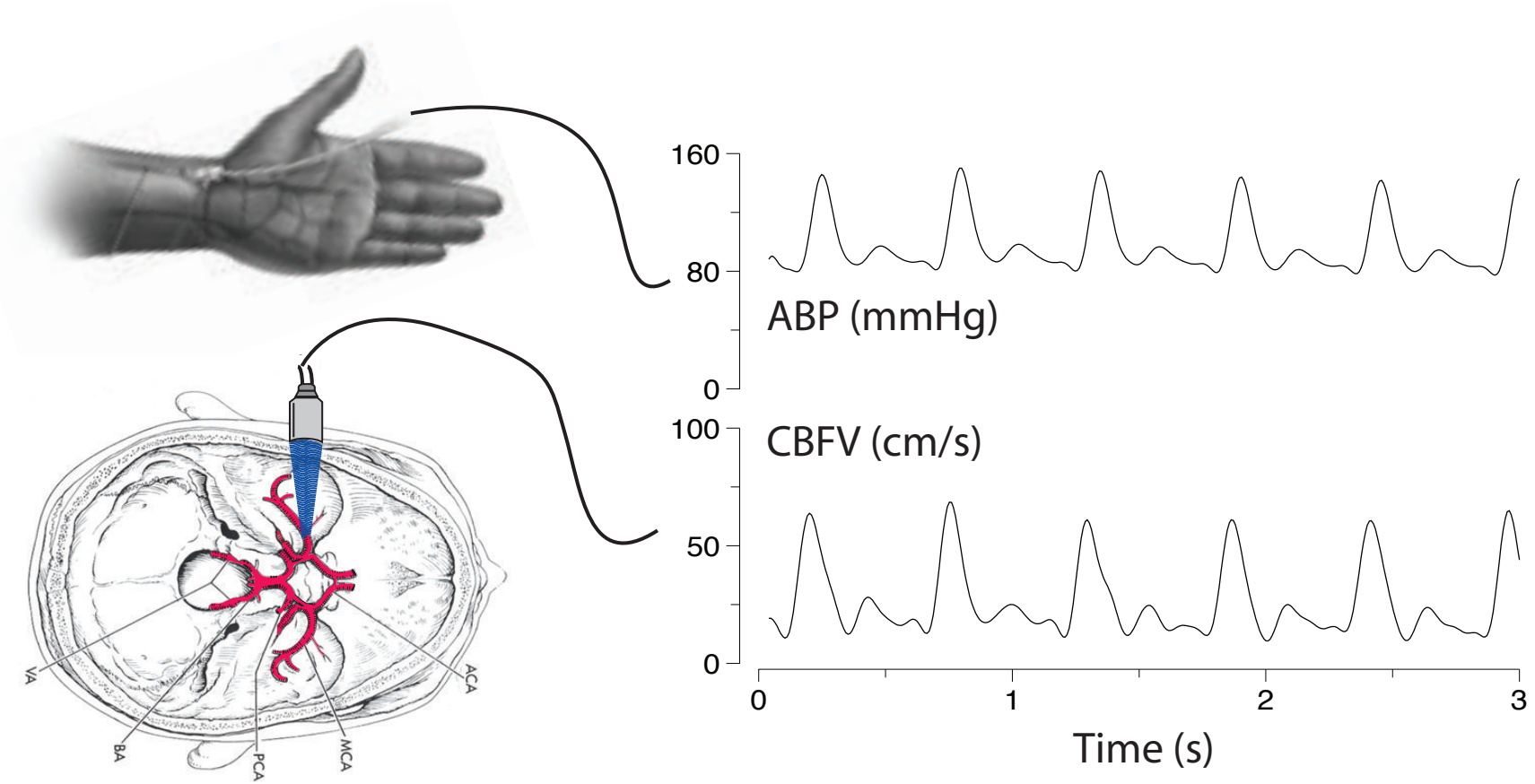
Circuit model quantitatively captures the quantitative relationship between input variables (ABP and CBF) and parameters (R, C, ICP).

Estimation Goal



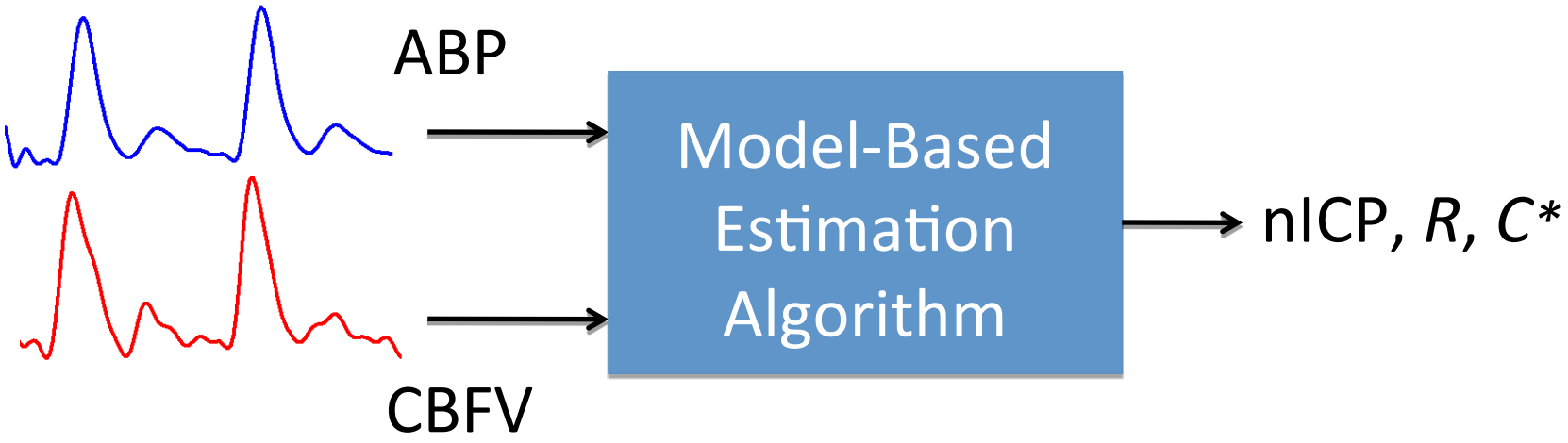
Process available measurements, imposing constraints derived from this model, to compute beat-by-beat estimates of *R*, *C,* and ICP.

Available Measurements



- Arterial blood pressure (at a peripheral site)
- Cerebral blood flow *velocity*

Summary View



- No population parameters or training
- No learning within the patient
- No calibration

* nICP estimated absolute; R and C estimated to within a constant scale factor.

Validation Data*

- 37 comatose severe-TBI patients; 35 hours of data

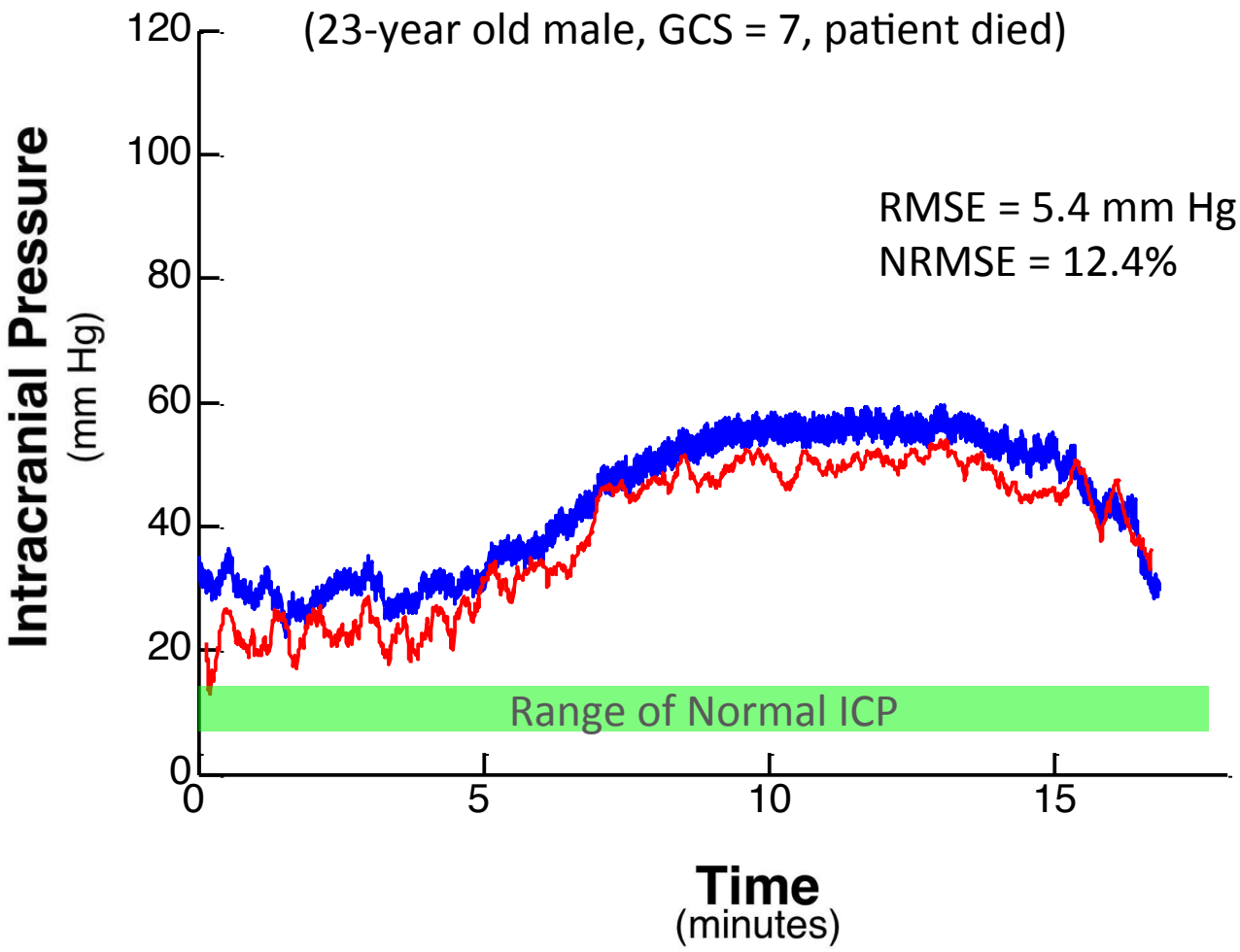
  (11 female/26 male; median age = 25, GCS = 5, 13 deaths in 6 months after hospitalization, only 6 patients had a good outcome)

- CBFV measurements via TCD (unilateral or bilateral)
- Radial ABP via an intra-arterial catheter
- ICP via parenchymal probe

- ICP measurements were revealed to us *post hoc*

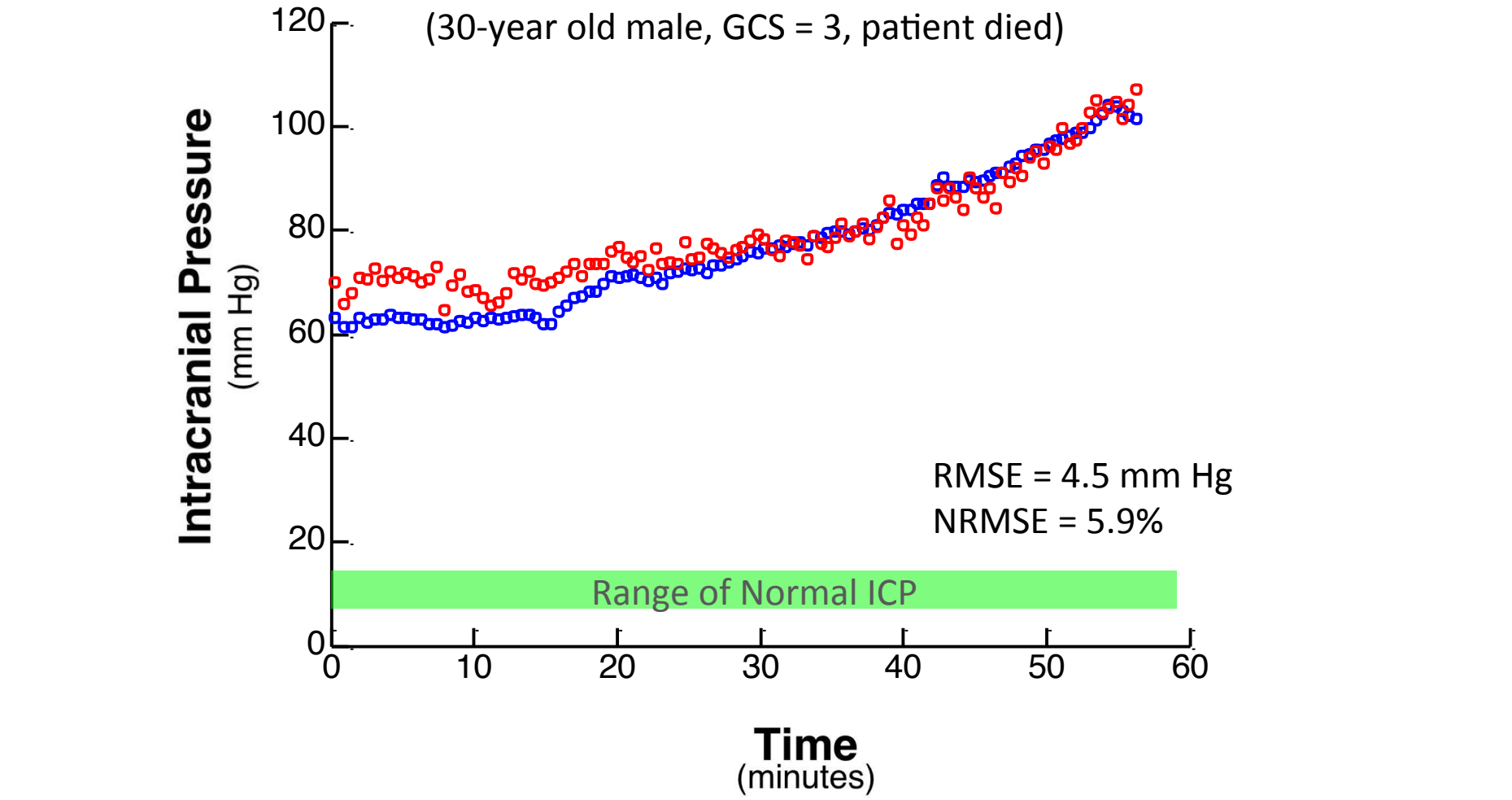
*Collected in the 1990s; courtesy of Prof. Czosnyka at Addenbrooke's Hospital, University of Cambridge, UK

Plateau Wave



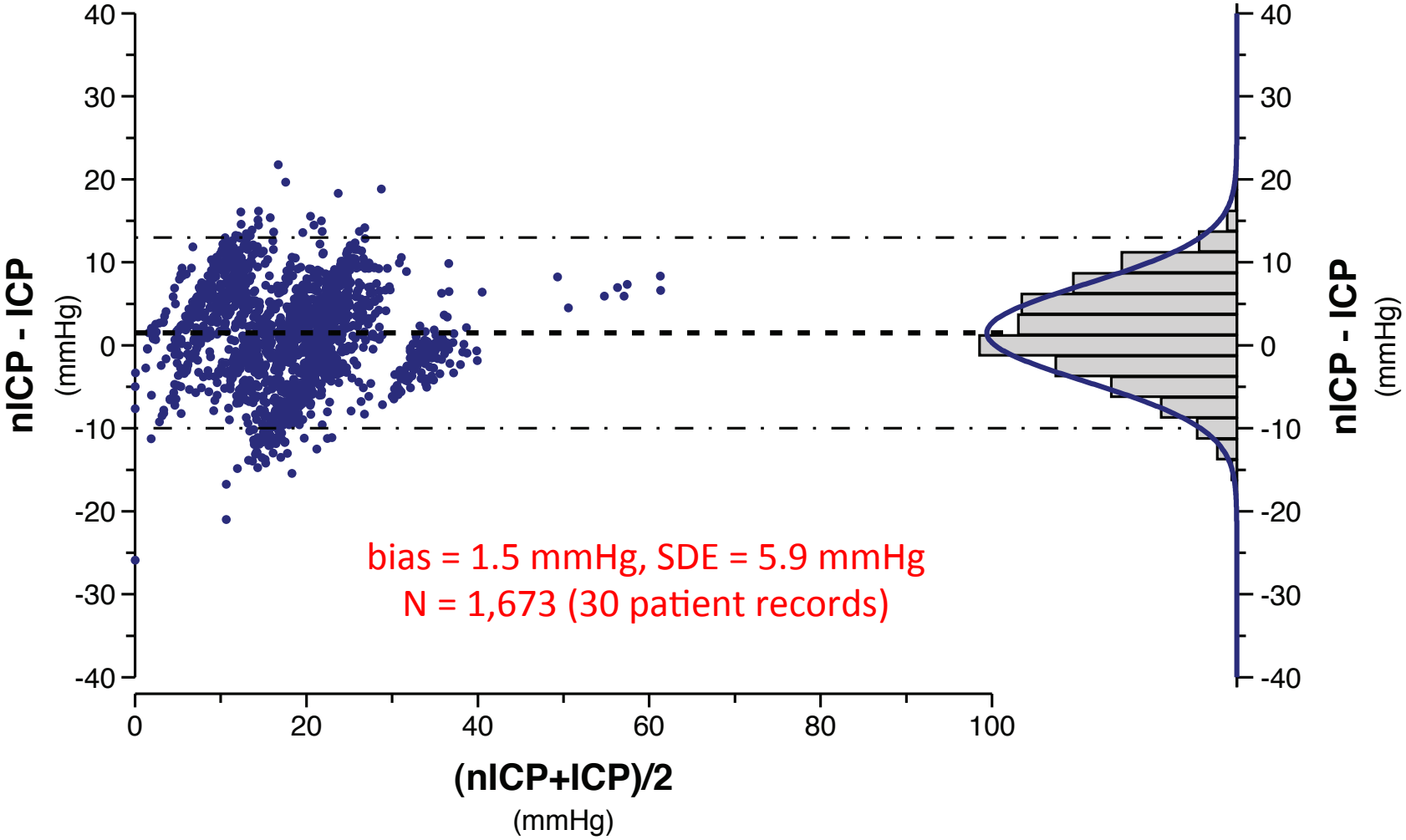
Kashif *et al*. Sci Transl Med 4(129), 2012.

Refractory Intracranial Hypertension



Kashif *et al*. Sci Transl Med 4(129), 2012.

Aggregate Results – Bilateral TCD



Kashif *et al*. Sci Transl Med 4(129), 2012.

Detection of Intracranial Hypertension

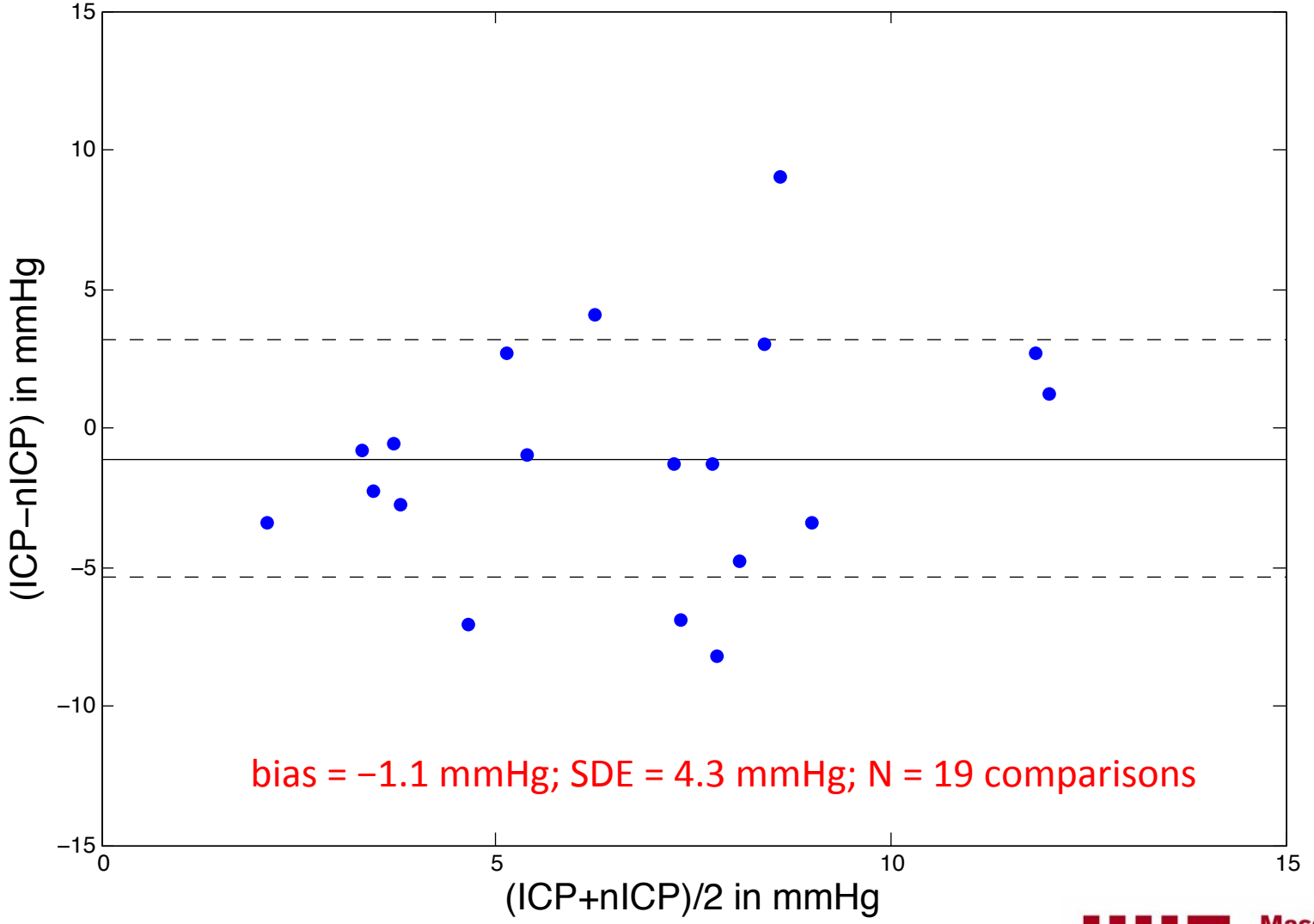
- Define ICH as *measured* ICP > 20 mmHg
- For nICP > 20 mmHg, declare ICH

For nICP averaged across all 45 patient records

Sensitivity = 90%
Specificity = 80%

Kashif *et al*. Sci Transl Med 4(129), 2012.

Subarachnoid Hemorrhage Patients



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Planned Hydrocephalus Study

- Children and young adults
- Assess ICP noninvasively before and after surgery for shunt placement/revision
- Measure ICP in the OR before and after shunt placement
- Determine agreement of absolute ICP and also in ICP reduction

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