Wide Variability of Intracranial Pressures Measured in Ventricular and Parenchymal Compartments Warrant the Use of Separate Terminology: A Systematic Review

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Currently ICP measurements are reported uniformly in the literature despite the compartment in which it is measured. We performed a literature review to identify the variability of ICP measurements between ventricular (ICP-v) and brain tissue (ICP-bt).

BACKGROUND

A variety of intracranial pressure (ICP) monitoring devices have been developed in years since 1866.

External ventricular drain (EVD) is often considered as the reference standard for ICP values.

Numerous other locations and monitoring systems (epidural, subdural, subarachnoid and intraparen-chymatous (IPM), fiber-optic) are now available.

Multiple studies describe statistically and clinically significant differences in ICP using IPM and EVD.

We propose two new terms that more accurately identify the anatomical structure for the referenced ICP:

- ICP-v = Intracranial pressure ventricular
- ICP-bt = Intracranial pressure brain tissue

OBJECTIVES

1. To identify literature related to simultaneous measurements of ICP using ventricular and parenchymal methods.
2. To assess the agreement in the measurements of both techniques.

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METHODS

Comprehensive literature search was performed for studies measuring ICP-v and ICP-bt simultaneously in adults in:

Medline | CINAHL | Embase | Scopus

Five authors individually reviewed the articles to meet our criteria. (Figure 1)

Figure 1: Study criteria

Search words:
Critical care, monitoring, intracranial pressure, ICP, epidural catheter, intracranial hypertension, ventriculostomy, ventricular drain, external ventricular drain, physiologic monitoring

Exclusion criteria:
Dissertations, case reports, abstracts, conference proceedings, books, reviews

Search limits:
English, full text, adult human subjects

Figure 2: Results literature search

47 articles reviewed

35 articles excluded
- 3- Pediatric population
- 3- No ICP data
- 5- Case studies
- 3- Non human subjects
- 21- Incomplete ICP-bt and ICP-v data

12 articles analyzed

RESULTS

Of the 47 articles reviewed, 12 were analyzed. (Figure 2 and Table 1)

Of the 12 studies: Six were comparative. Four were observational and two cross-sectional design.

There was **time of publication influence** in the design of studies:

- Earlier studies: retrospective and compared EVD and IPM values.
- Later studies: prospective and confirmed that increases in ICP values resulted in smaller differences between ICP-bt and ICP-v values.

Compartmental difference: Slavin & Misra found differences between the infratentorial and supratentorial ICP (between 2 to 8 mmHg).

Drain status open or closed: ICP-bt and ICP-v Difference between the open and closed status of EVD: Vender et al. demonstrated ICP-bt and ICP-v lack correlation when the drain is open vs. closed.

Variability of measurements between ICP-bt and ICP-v ranges:

- ±7 mmHg (Lescot et al.)
- ±3 mmHg (Berlin et al.)

Absolute ICP values dictate variability in correlation between ICP-bt and ICP-v: (Mahdavi et al.)

- Best with ICP values beyond 25 mmHg in either (r=0.61)
- Less if ICP <25 mmHg in either monitors (r=0.42)
- Questionable if ICP <20 mmHg (r=0.36)

Correlation of ICP-bt and ICP-v are determined by open drain status and by the actual value of the ICP measured.

1st Author (year)	Study Design	Population	Sample Size	Comparison
Gambardella (1992)	R	SAH, ICH, TBI, HCP, Tumor	209	Absolute ICP values from the EVD and from the IPM. The overall correlation coefficient was 0.946 (range: 0.586 to 0.996).
Shapiro (1996)	R	SAH, ICH, TBI, Edema, AVM, Tumor	244	Very strong correlation between the IPM and EVD catheter in the first measure taken (r=0.97).
Khan (1998)	R	SAH, ICH, TBI, Tumor	156	Complication were encountered in 46 cases (29.4%). 25% for EVD and 4.4% for IPM (p<0.0001).
Chambers (2001)	P	Not stated	11	The mean difference was less than 0.1 mmHg (EVD–Spiegelberg) with an SD of 4.9 mmHg.
Mack (2003)	P	Aneurysmal SAH	233	There was a strong propensity to favor placement of EVD over IPM, especially in poor-grade patients.
Slavin (2003)	R	ICH, AVM, Tumor	5	The difference between the infratentorial and supratentorial ICP readings ranged from 2-8 mmHg.
Koskinen (2005)	P	Multiple diseases	128	Mean EVD = 18.30 ± 3.0 mmHg; Mean IPM = 19.0 ± 0.2 mmHg; r=0.79, p<0.0001
Timofeev (2008)	P	TBI	24	A significant correlation (r=0.51, p=0.031) between the degree of decrease in ICP and PbtO2 increase.
Vender (2011)	P	TBI	11	Parenchymal and ventricular monitors showed no significant mean difference in open (p=0.22) or closed (p=0.38) positions.
Lescot (2011)	R	SAH, TBI, AVM, Tumor	30	Parenchymal ICP approximated the ventricular CSF pressures by ±7 mmHg.
Berlin (2015)	P	SAH, TBI, ICH	35	Paired observation with difference of ±3 mmHg = 93%; 4-8 mmHg = 7%; ≥9 mmHg = <1%
Mahdavi (2016)	R	TBI	37	Paired t tests found significantly different (p<0.001) ICP values recorded by EVD and IPM. EVD/IPM correlation was weaker (r=0.36) in lower values (<20 mmHg).

R = Retrospective; P = Prospective

Table 1: Studies selected for systematic review and their details

CONCLUSION

- Existing literature does not differentiate the difference between the measurement of ICP in different compartments or its source.
- Variability between the modalities of measurements of ICP exist and are determined by: Compartment of measurement, Actual ICP value, and Status of the drain.
- It is important to report ICP-v and ICP-bt as distinctly different measures.