RESEARCH

Clinical Signs of Basilar Skull Fracture and Their Predictive Value in Diagnosis of This Injury

Cibele Andres Solai, MSN, RN ■ Cristiane de Alencar Domingues, PhD, RN ■
Lilia de Souza Nogueira, PhD, RN ■ Regina Marcia Cardoso de Sousa, PhD, RN

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ABSTRACT

Although clinical signs for the diagnosis of basilar skull fracture (BSF) are ambiguous, they are widely used to make decisions on initial interventions involving trauma patients. We aimed to assess the performance of early and late (within 48 hr posttrauma) signs for BSF diagnosis and to verify the correlation between the presence of these signs and head injury severity. We conducted a prospectively designed follow-up study at a referral hospital for trauma care in Sao Paulo, Brazil, and performed structured observations for 48 hr post-blunt head injury in patients aged 12 years or older. The following signs of BSF were considered: raccoon eyes, Battle's sign, otorrhea, and rhinorrhea. Among the 136 enrolled patients (85.3% male; mean age 40 ± 21.4 years), 28 patients (20.6%) had BSF. The clinical signs for the early or late detection of BSF had low accuracy (55.9% vs. 43.4%), specificity (52.8% vs. 30.5%), and positive predictive value (25.7% vs. 27.1%). However, the presence of these signs was correlated to head injury severity, indicated by the Glasgow Coma Scale ($p = .041$) and Maximum Abbreviated Injury Scale–Head region ($p = .002$). In view of the low accuracy of these signs, resulting low clinical value of their presence, and their high sensitivity in the late stage, the study results contraindicate the value of BSF signs for making decisions about using the nasal route for the introduction of catheters and tubes in initial trauma care.

Key Words

Basilar skull fracture, Cranial fractures, Head injury, Signs and symptoms

Among head injuries, basilar skull fracture (BSF) is one of the life-threatening injuries (Association for the Advancement of Automotive Medicine [AAAM], 2008; Nuyttens & Belleghem, 2014) and stands out because of the risk of complications. As the bones at the base of the skull are very fragile and located close to the dura mater, meningeal lesion and liquor fistulas are frequent consequences of this type of fracture. Other possible complications are cranial nerve palsies, cerebrovascular lesions, and orbital and intracranial lesions (Archer, Sun, & Bonney, 2016; Baugnon & Hudgins, 2014; Jain, McCunn, Smith, & Pittet, 2016; Moustoukas & Litwin, 1983; Simon & Newton, 2017; Somasundaram, Laxton, & Perrin, 2014).

In addition, BSF exposes patients to the risk of adverse events due to the possibility that catheters and tubes, introduced via the nasal route, move beyond the fractured area and reach the brain. Case reports in the literature describe the complications caused by nasal gastric catheterizations and tracheal cannulations, such as the placement of tubes and catheters in the intracranial region as a result of "false passage" (Casagli, Malacarme, Tosi, & Biancofiore, 1994; Castiglione et al., 1998; Chandra & Kumar, 2010; Ellis, Lambert, & Shirley, 2006; Ferreras, Junqueira, & Garcia-Consuegra, 2000; Genu, de Oliveira, Vasconcellos, Nogueira, & Vasconcelos, 2004; Martin et al., 2004; Pandey et al., 2004; Rahimi-Movaghar, Boroojeny, Moghtaderi, & Keshmirian, 2005; Steinbruner, Mazur, & Mahoney, 2007; Yam, Roka, Shrestha, & Puri, 2010).

In the initial phase of care for head-injured patients, the lower level of consciousness can lead to loss of airway protection capacity and insufficient cerebral oxygen supply. Airway problems in trauma can also be caused by hemorrhages and edema, facial injuries, hematomas in the floor of the mouth or soft palate, nasal bleeding, relaxation of the tongue under the hypopharynx, vomiting, secretions, excessive salivation, and respiratory changes. In any case, airway problems require immediate interventions, such as intermittent aspiration, establishment of a safe airway, and oral or pharyngeal cannulation, besides gastric catheterization, in the initial care of head-injured patients (Jain et al., 2016; National Association of Emergency Medical Technicians [NAEMT], 2016; Simon & Newton, 2017). The safe performance of these interventions requires adequate materials and a complication-free access pathway, which rules out the use of the nasal route in BSF patients because of the risk of false passage and deviation of the device to the brain region.

Author Affiliations: School of Nursing, University of São Paulo, Sao Paulo, SP, Brazil (Mss Solai and Drs Nogueira and de Sousa); and All Trauma, Sao Paulo, SP, Brazil (Dr Domingues).

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Correspondence: Cristiane de Alencar Domingues, PhD, RN, Rua Engenheiro Agrônomo Guaracy Ribeiro Monteiro, 345, Apto 188, Ribeirão Preto 14026-574, SP, Brazil (crismingues@gmail.com).

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Previous studies indicate that BSF can be recognized by the following clinical findings: hemotympanum, Battle's sign, otorrhea, rhinorrhea, and raccoon eyes (AAAM, 2008; Archer et al., 2016; Baugnon & Hudgins, 2014; Jain et al., 2016; NAEMT, 2016; Simon & Newton, 2017; Somasundaram et al., 2014; Yellinek, Cohen, Merkin, Shelef, & Benifla, 2016). Advanced trauma care manuals (American College of Surgeons, 2017; NAEMT, 2016) emphasize the presence of these BSF signs as parameters for decisions about possible treatment strategies. However, the signs do not always manifest early (McPheeters, White, & Winter, 2010; Rajda, 2004; Tubbs, Shoja, Loukas, Oakes, & Cohen-Gadol, 2010). In addition, the specificity of these signs is discussed, as their presence does not always confirm BSF and the absence of these clinical findings does not exclude this lesion.

This discrepancy and the great emphasis of clinical practice recommendations (Flores & Casulari, 2003; McPheeters et al., 2010; NAEMT, 2016; Tubbs et al., 2010) on the relationship among the presence of clinical signs, diagnosis of BSF, and interventions in the initial care of trauma patients gave rise to concerns that resulted in the current research study. This study aims to assess the performance of the early and late clinical signs of BSF for diagnosis of this injury and to verify the correlation between the presence of these clinical signs and the severity of head injury.

METHODS

This was a prospective follow-up study with structured observation of head-injured patients up to 48 hr posttrauma. The research was conducted between August 2012 and January 2013 at a university hospital that is a referral institution for trauma care in Sao Paulo (Brazil). The sample population included all patients, aged 12 years or older, with blunt head injury who were treated at the hospital within 2 hr after the trauma was caused. Patients without signs of BSF, who died, or who were discharged in less than 48 hr posttrauma were excluded from the study.

The clinical signs of BSF considered in the study were raccoon eyes, Battle's sign, otorrhea, and rhinorrhea, as described in the Abbreviated Injury Scale (AIS) 2005 Update 2008 (AAAM, 2008). The AIS is used to describe the injuries resulting from a trauma and to determine their severity. The list of lesions is presented in a manual that provides, for each injury described, an identifier composed of seven numbers, the seventh digit being the value of the AIS severity score. The AIS score can range from 1 to 6, with 1 assigned to minor injuries, 2 to moderate, 3 to serious, 4 to severe, 5 to critical, and 6 to lesions of maximum severity (AAAM, 2008).

Basilar skull fracture is diagnosed by direct visualization by a neurosurgeon during surgery or via computed tomography of the skull (tomographic sections <5 mm). The presence of fracture lines in the bones of the orbit, ethmoid, sphenoid, and basilar processes of the occipital bone and mastoid, squamous, and petrous portions of the temporal bone (Archer et al., 2016; Baugnon & Hudgins, 2014; Jain et al., 2016; Simon & Newton, 2017; Yellinek et al., 2016) was considered positive results.

Head injury severity was estimated using the Glasgow Coma Scale (GCS) score, calculated during the neurosurgeon's first evaluation (mild: GCS score = 13–15; moderate: GCS score = 9–12; severe: GCS score = 3–8) (Teasdale et al., 2014) and the Maximum Abbreviated Injury Scale–Head region (MAIS/head).

The MAIS is an indicator that describes the severity of the most serious injuries of trauma patients, and its coefficient corresponds to a patient's highest AIS score, regardless of the number of injuries (AAAM, 2008; Nuyttens & Belleghem, 2014). The MAIS, like the AIS, ranges from 1 to 6 points. In this study, we analyzed the MAIS score only for the head region.

The researchers and assistants were previously trained to examine the patients and fill out the research data registration tool. The work of the data collection assistants was assessed during the pretest study, and the researchers periodically monitored the assistants. All patients included in the study were monitored from the admission to the emergency department (ED) until the detection of clinical signs of BSF or until 48 hr posttrauma.

To test the performance of the clinical signs for identifying BSF, we calculated the following indicators: positive predictive value (PPV), negative predictive value (NPV), sensitivity, specificity, and accuracy. These indicators were calculated for the clinical signs detected within 1 and 48 hr after admission to the ED.

To analyze the correlation between the presence of clinical signs of BSF and head injury severity (GCS and MAIS/head), we applied Pearson's chi-square test with a 5% significance level.

We obtained approval for the study from the institution's Research Ethics Committee (CEP/CSSM 15/12), and the participants or legal caregivers, if the patient was unable to express himself/herself, signed the free and informed consent form.

RESULTS

Initially, 172 individuals, aged 12 years or older, with suspected blunt head injury who were treated in the ED during the data collection period were selected. After applying the exclusion criteria, 136 individuals were enrolled in the study.

Of the 36 subjects excluded from the study, 19 patients (52.8%) showed no signs of BSF and left the hospital within 48 hr after the trauma, 13 patients (36.1%) had no confirmed head injury diagnosis, and four patients

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TABLE 1 Head Injury Patients According to the Presence of BSF and Clinical Signs of the Injury in the Initial Assessment at the Emergency Department and Up to 48 hr Posttrauma

	Yes, *n* (%)	No, *n* (%)	Total, *n* (%)
Clinical signs of BSF (Initial)			
Yes	19 (14.0)	9 (6.6)	28 (20.6)
No	51 (37.5)	57 (41.9)	108 (79.4)
Total	70 (51.5)	66 (48.5)	136 (100.0)
Clinical signs of BSF (Up to 48 hr)			
Yes	26 (19.1)	2 (1.5)	28 (20.6)
No	75 (55.1)	33 (24.3)	108 (79.4)
Total	101 (74.2)	35 (25.8)	136 (100.0)

Note. *BSF = basilar skull fracture.*

(11.1%) were admitted to the study site more than 120 min posttrauma.

Most patients were male (85.3%), and the mean age was 40 ± 21.4 years. Pedestrians and motorcyclists (40.5%) prevailed, followed by patients with a fall (38.2%). Mild head injury was the most frequent injury (72.0%), according to the GCS, and most patients (59.6%) had a MAIS/head score between 1 and 2.

As listed in Table 1, BSF was diagnosed in 28 patients (20.6%), and 101 patients (74.2%) presented at least one of four investigated signs of BSF (raccoon eyes, Battle's sign, otorrhea, and rhinorrhea) within 48 hr posttrauma.

Of the 28 patients with a diagnosis of BSF, 19 patients presented early clinical signs of the injury (initial assessment at the ED). Within 48 hr posttrauma, the clinical signs of BSF appeared in seven additional patients and, in two cases, no clinical sign was observed during the 48 hr despite a diagnosis of BSF.

The data in Table 2 reveal low accuracy, specificity, and PPV of the clinical signs in the early (within 1 hr posttrauma) or late (within 48 hr posttrauma) detection of BSF. The performance of the clinical findings at these two time points (early and late) was similar to the predictive values. Nevertheless, considerable differences were observed in the sensitivity and specificity of these signs. Specificity improved at the cost of a large reduction in sensitivity when the early clinical findings at the ED were considered.

TABLE 2 Performance of Clinical Signs for Diagnosis of BSF in the First Assessment at the Emergency Department and Later (Up to 48 hr)

Indicator	Initial	Up to 48 hr
Positive predictive value	27.1%	25.7%
Negative predictive value	86.4%	94.3%
Sensitivity	67.8%	92.8%
Specificity	52.8%	30.5%
Accuracy	55.9%	43.4%

Note. *BSF = basilar skull fracture.*

In Table 3, the correlation between the presence of signs of BSF and head injury severity is presented, as indicated by the GCS (p = .041) and MAIS/head scores (p = .002). Indication of severe head injury by the GCS and scores of 3, 4, and 5 on the MAIS/head were more frequent in patients with signs of BSF.

DISCUSSION

Previous studies (Casagli et al., 1994; Ferreras et al., 2000; McPheeters et al., 2010) report that the clinical signs of BSF do not manifest immediately and that its onset can be delayed by 1 or 2 days posttrauma (Flores & Casulari, 2003; Pretto Flores, De Almeida, & Casulari, 2000). The results of this study show that these signs were present in 51.5% of the patients during the initial evaluation in the ED and in 74.2% of the patients within 48 hr posttrauma. In addition, among the 26 case patients who presented clinical signs of BSF and were diagnosed with this injury, seven did not present signs within 1 hr posttrauma.

In the current study, the clinical findings correctly indicated the presence of BSF, early in 55.9% of the patients and later in 43.4% of the patients. The PPV of the signs was 27.1% and 25.7%, that is, approximately 25% of the patients had signs of BSF, and the diagnosis was confirmed via computed tomography or surgery. The NPV of the signs corresponded to 86.4% initially and 94.3% at the end of the evaluation period. Nine and two BSF patients had no early or late signs of this lesion, respectively.

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TABLE 3 Comparison of Patients According to the Presence of Signs of BSF and Severity of Head Injury

Severity of Head Injury	Clinical Signs of BSF		
	Yes, *n* (%)	No, *n* (%)	p^a
GCS			
Mild (13–15)	(66.3)	31 (88.6)	**.041**
Moderate (9–12)	10 (9.9)	1 (2.8)	
Severe (3–8)	24 (23.8)	3 (8.6)	
MAIS/head			
MAIS 1 or 2	48 (50.5)	34 (82.9)	**.002**
MAIS 3	35 (36.8)	6 (14.6)	
MAIS 4 or 5	12 (12.7)	1 (2.5)	

Note. *BSF = basilar skull fracture; GCS = Glasgow Coma Scale; MAIS = Maximum Abbreviated Injury Scale.*
[a]Pearson's chi-square test.

The sensitivity of BSF signs was initially low (67.8%) but improved to 92.8% within 48 hr after the trauma. In contrast, the specificity was already low initially (52.8%) and decreased further to 30.5% at the end of the observation period.

Overall, the signs had reduced accuracy, specificity, and low PPV, indicating little clinical value of these signs. The sensitivity of the BSF signals and the NPV were higher, though, showing that the absence of these clinical findings was more important than their presence in relation to the diagnosis of BSF, especially at the end of the evaluation period.

Considering the signs detected within the first hour postadmission, higher accuracy (55.9% vs. 43.4%) and specificity (52.8% vs. 43.4%) levels were found than at the end of the evaluations. In addition, the sensitivity was significantly increased (67.8% vs. 92.8%).

High sensitivity of a test or signal is relevant when the penalty for failing to diagnose a disease is great and when it is important to establish that a disease is unlikely (Fletcher, Fletcher, & Fletcher, 2012), as it is the case with BSF in initial trauma care. Our analysis of the indicators showed that they are of little clinical relevance in the initial evaluation, as accuracy, specificity, and sensitivity of the BSF signs are low.

It should be recalled that the early diagnosis of BSF is of particular interest for the initial care due to the risk of false passage when using the nasal route to perform procedures at a time when the result of the computed tomography is not yet available.

This study confirmed the late onset of BSF signs and its results limit the value of BSF signs in the initial care of trauma patients. While the presence of BSF signs has little clinical value, their absence presents good NPV in the late stage. About one of four patients with BSF and clinical signs are diagnosed with BSF after the first posttraumatic assessment.

In addition to this observation, nine patients (32.14% of cases with BSF) displayed no signs of BSF in the first evaluation in the ED. The absence of signs did not indicate a low possibility of this lesion. Therefore, even without evidence of BSF, nurses should pay attention to head-injured patients and consider them as probable cases of BSF until the outcome of computed tomography excludes the possibility of this lesion.

It is also worth mentioning that the presence of clinical signs of BSF correlated to the severity of head injury. The scientific literature has pointed out that the greater the severity of head injury, the higher the frequency of skull fractures. Most patients (65.0%) with a moderate and severe head injury admitted for neurosurgical evaluation have cranial fractures, which are present in 80.0% of fatal cases (Castiglione et al., 1998). Basilar skull fracture is diagnosed in about 6% (Archer et al., 2016; Simon & Newton, 2017; Yellinek et al., 2016) of cranial trauma cases and accounts for 19.0% of fractures (Flores & Casulari, 2003). In severe head injuries, the incidence rate of BSF is 46.0% (Potapov et al., 2004).

In our study, 20.6% of the patients had a diagnosis of BSF and 74.2% of the patients presented signs of BSF within 48 hr after trauma. The group of patients with BSF signs showed more frequently indications of severe head injury, both by the GCS and the MAIS/head. Therefore, these signs alone indicated the presence of severe cranial lesions.

Researchers have indicated that patients with clinical signs of BSF usually have significant impact on the skull and have a high probability of brain injury (Flores & Casulari, 2003; Pretto Flores et al., 2000). Research on clinical signs of BSF indicated that patients with these signs have a sixfold higher chance of having a fracture on the computed tomographic scan and a fourfold increased risk of associated brain injury when compared with patients not displaying these signs. The authors argue that these signs should be considered as independent markers of head injury severity (Flores & Casulari, 2003).

CONCLUSION

These study results indicate a limited value of BSF signs in deciding whether to use nasal catheter and tube introduction in initial trauma care.

For clinical practice, the results discourage the use of the nasal route in all patients with suspected head injury and emphasize that during the nasal aspiration procedure, the use of a rigid device is fundamental to avoid false passage of the aspiration tube from the nasal to the intracranial region, which is possible in patients presenting BSF.

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It should be highlighted, however, that the presence of clinical signs of BSF indicates a severe head injury and therefore should be considered an alert signal for this type of injury.

LIMITATIONS

These data were collected at a university teaching hospital that is a referral institution for trauma care, with higher incidence rates of severe trauma and more enhanced diagnostic techniques. As a result, the assertions regarding PPV may be higher. Therefore, it should be emphasized that, in this study, the PPV of the BSF signs corresponded to 25.7%, lower than that reported in previous publications (Flores & Casulari, 2003; Pretto Flores et al., 2000).

The exclusion criteria for this study, which eliminate patients without signs of BSF and discharge or death before 48 hr posttrauma, may have changed the results of the performance indicators.

The most incident trauma mechanism among the participants may have contributed to differences between these results and other publications. Cranial vault fractures are associated with falls that result in isolated and severe head injuries, whereas BSF is more common in car collisions, provoked by a strong force (Baugnon & Hudgins, 2014). Patients from the latter group comprised a larger proportion of the patients in our study (40.5% of the cases).

KEY POINTS

- The study results demonstrate low accuracy, specificity, and PPV coefficients for detection of BSF, limiting the value of these signs in decision making on intervention strategies in initial care for trauma patients.
- The research results discourage nasal application of catheters and tubes in all patients with suspected head injury and emphasize that, if nasal aspiration is necessary, a rigid catheter should be used to avoid false passage in BSF patients.
- Clinical signs of BSF can be considered as important indicators of the severity of head injury.

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