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ORIGINAL ARTICLE

Swallowing Disorders in Severe Brain Injury in the Arousal Phase

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Abstract The objective of this study was to determine the clinical characteristics of swallowing disorders in severe brain injury in the arousal phase after coma. Between December 1, 2013 and June 30, 2014, eleven patients with severe acquired brain injury who were admitted to rehabilitation center (Male 81.8 %; 40.7 ± 14.6 years) were included in the study. Evaluation of swallowing included a functional examination, clinical functional swallowing test, and naso-endoscopic swallowing test. All patients had swallowing disorders at admission. The first functional swallowing test showed oral (77.8 %) and pharyngeal (66.7 %) food bolus transport disorders; and alterations in airway protection mechanisms (80 %). Swallowing test under endoscopic control showed a disorder in swallowing coordination in 55.6 % of patients tested. Seven (63.6 %) patients resumed oral feeding within an average of 6 weeks after admission to rehabilitation center and 14 weeks after acquired brain injury. Six (85.7 %) of these seven patients continued to require modified solid and liquid textures. Swallowing disorders are a major concern in severe brain injury in the arousal phase. Early bedside assessment of swallowing is essential for detection of swallowing disorders to propose appropriate medical rehabilitation care to these patients in a state of altered consciousness.

Keywords Swallowing disorders · Disorders of consciousness · Severe acquired brain injury · Deglutition · Deglutition disorders

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Introduction

Swallowing disorders are a common impairment after brain injury, and it is estimated that 37–78 % of patients have swallowing disorders in the acute phase of stroke [1]. The frequency of swallowing disorders appears to be higher in the early phase of traumatic brain injury (TBI), involving 93 % of patients after ventilator weaning [2]. Swallowing disorders may occur during oral, pharyngeal, and esophageal phases [3] in both TBI [4] and stroke patients [5]. On videofluoroscopy, these patients often present delayed or no swallowing reflex, impaired lingual control, a decrease in pharyngeal peristalsis, and a few patients present laryngeal and cricopharyngeal dysfunction [5]. An increase in oral transit time, piecemeal deglutition; reduced palatoglossal closure, pharyngeal residue; increased pharyngeal delay time and pharyngeal transit time; airway penetration; and airway aspiration (before, during, or after swallowing) may also be observed [6].

In patients with severe brain injury, the major difficulty is testing deglutition. Many bedside swallowing assessments are available for patients with impaired consciousness. Coombes et al. proposed Facial Oral Tract Therapy (FOTT) which includes assessment and rehabilitative management of swallowing disorders [7]. Bicego et al. [8] and Hansen et al. [2], respectively, suggested FOTT for patients with impaired consciousness and after severe TBI.

Other assessments include the functional oral intake scale (FOIS) [9], the gugging swallowing screen (GUSS) [10], the Mann assessment swallowing ability (MASA) [11], and the volume–viscosity swallow test (V-VST) [12]. According to Bleeckx, patients may also be evaluated, regardless of the etiology of swallowing disorder, by medical and clinical functional examination [13]. Woisard et al. suggest clinical and speech therapy examination in addition to anatomic and dynamic examination by nasal endoscopy, and fiberoptic endoscopic evaluation of swallowing (FEES) [14]. To our knowledge, there is no standard reference for bedside swallowing assessment in severe brain injury.

Even if some swallowing disorders are clinically evident, silent aspirations without cough reflex may occur in half of all cases [15]. Since silent aspirations may be either alimentary or salivary, they may arise either with or without oral intake. Swallowing disorders increase the risk of malnutrition, dehydration, and respiratory infections, which increase morbidity [16–19] and mortality [19]. They involve increased length of hospitalization and associated healthcare costs [19]. Therefore, management of swallowing disorders after acquired brain injury seems to be an important issue whether short, medium, or long term. In this context, characterization of swallowing disorders should be a priority. Clinical examination is mandatory to set up appropriate care, right from the arousal phase, when the state of consciousness can still be altered [8]. It is essential to integrate this care support into the overall and multidisciplinary rehabilitative care management of patients. Thus, food intake, including texture, volume, taste, and temperature, as well as technical adjustments including posture, dentures, and enteral feeding by gastrostomy if necessary [16, 20–24] should be considered.

Hence, the main objective of this present study was to determine the clinical and naso-endoscopic characteristics of swallowing disorders and oropharyngeal dysphagia in severe brain injury in the arousal phase after coma. The secondary objective was to compare the initial clinical characteristics of patients with severe TBI having resumed oral feeding and patients unable to resume oral feeding 3 months after admission to our specialized rehabilitation unit.

Methods

This prospective study was conducted between December 1, 2013 and June 30, 2014. We prospectively and consecutively recruited all patients who completed inclusion criteria: age 18 years and over and admitted to a specialized unit of the Physical Medicine and Rehabilitation Center after a severe acquired brain injury, whether traumatic or non traumatic. Written consent for the anonymous use of data was systematically collected from the contact person for the patient. Exclusion criteria were preexisting pathologies affecting swallowing, whether neurological, central or peripheral, neuromuscular, or otolaryngological.

Sociodemographic characteristics were collected from the patient's medical records at admission. Additional information was sought from the family and/or relatives regarding the patient's laterality. Data on comorbidities affecting swallowing were sought. The following medical data on the initial disease and acute phase of acquired brain injury were also collected: the date, cause, and context of the brain injury; initial Glasgow Coma Scale (GCS) score [25]; initial assessment of the lesions including primary focal and diffuse encephalic lesions [26], facial injuries, and extracranial lesions; time between the onset of severe brain injury and admission to the unit; duration of orotracheal intubation; placement of tracheostomy, gastrostomy, or cerebral ventricular shunt; the occurrence of a respiratory infection during intensive care unit (ICU) stay; the occurrence of events generating secondary encephalic lesions [26], in particular secondary cerebral insults of systemic origin [27, 28]; and intra cranial pressure (ICP) >20 mmHg [29]. Two groups were distinguished: patients with severe TBI and patients without TBI. TBI was considered severe if GCS was ≤ 8 with eyes closed after correction of vital functions [30], immediately or after a free interval provided that the coma had lasted at least 6 h [31]. We considered that patients who did not have TBI had a severe brain injury, if they had a history of disease with coma in the initial phase during ICU stay, and persistence of disorders of consciousness after coma which indicated their admission to our specific unit.

An initial clinical evaluation was carried out at admission to a specialized unit of our rehabilitation center. Data on the patient's overall medical condition at time of inclusion were collected as follows: nutritional status, placement of tracheostomy tube, bronchial congestion, and anomalies of the upper limbs. The Wessex Head Injury Matrix (WHIM) [32] was used for neurological measurement of the patient's level of vigilance and consciousness. This scale is used in routine practice in our unit. Patients were considered to be in a vegetative state with a score between 1 and 15, minimally conscious with a score between 16 and 46. With a score between 47 and 62, patients with severe TBI were considered to be in emerging post-traumatic amnesia (PTA), and patients without severe TBI were considered to be in a confusional state. The Galveston Orientation and Amnesia Test (GOAT) [33] was used to assess post-traumatic amnesia status in patients with severe TBI. Data on the patient's ability to focus, run a simple command, and presence of a motor and/or sensory deficit were also sought.

A second clinical evaluation focused on swallowing.

First, a clinical functional swallowing test was performed. The patient was placed in a quiet environment with no sound or sight distraction, sitting opposite to and at the same level as the investigator. The positions required for safe oral food intake were sought: cervicocephalic tonus for maintaining straight head, trunk tonus enabling sitting position in a wheelchair or recumbent in bed for more than 30 min, and the ability to execute a coordinated hand/mouth movement whether spontaneously or on request. Prerequisites for administration of the clinical functional swallowing test were then sought: at least a 15-min attention span, voluntary coughing and throat clearing, salivary swallowing on request without drooling or wet voice [10], and the absence of respiratory infection. Then, the clinical functional swallowing test was performed under saturation control by pulse oximetry [34]. Three different textures (compote: an industrial preparation of sweetened stewed apples, sparkling water, and still water), and two different sizes (a teaspoon and half a plastic cup) were used. Boluses were administered in cervical anteflexion position. Food intake was in four steps as follows: (1) a teaspoon of compote, (2) a teaspoon of sparkling water with mint syrup, (3) a teaspoon of still water with mint syrup, and (4) half a glass of still water with mint syrup. The mint syrup was used to search for oral residue. The swallowing test was ended on completion of the different consistency and volume tests, or if swallowing safety was altered (coughing, voice change, or desaturation (more than 3 % by pulse oximeter). Swallowing disorders observed during the functional swallowing test were classified as impaired airway protection mechanisms (safety), and impaired bolus transport, distinguishing disorders of oral transport and disorders of pharyngeal transport. Oral transport disorders were defined by an oral time over 2 s [3], drooling, or oral residue and pharyngeal transport disorders were defined by multiple swallows or pharyngeal residue.

Second, a nasal endoscopy was performed to assess cranial nerve dysfunction and swallowing test under visual control. Nasal endoscopy was carried out by a trained operator, with the help of a nasal fiberscope (ENF-GP Olympus Medical Systems Corp Tokyo Japan). Damage to cranial nerves IX, X, and XII was sought by assessing the mobility of the palate, pharynx, larynx, glottis, and the base of the tongue, as well as disorders of pharyngolaryngeal sensitivity [35]. This also allowed search for salivary stasis and aspirations with or without cough reflex. Endoscopic examination also enabled administration of swallowing test under endoscopic control, seeking impaired coordination of swallowing, direct aspiration with or without coughing, and pharyngeal residue [36–38]. Return to oral food intake was decided after the functional swallowing test and the swallowing test under endoscopic control. Return to oral intake capacity was evaluated by using the FOIS [9].

Major complications in swallowing disorders (significant weight loss $\geq$2 % of body weight in a week and bronchopulmonary infection [16–19]) were also collected.

Data were analyzed using BiostaTGV (http://marne.u707.jussieu.fr/biostatgv/). Fisher's exact test was used for categorical variables, and median and mean calculations. Student's t test was used for quantitative variables. The alpha risk was 5 %, with a significance of $p < 0.05$. A probability of 5 % was taken to indicate a statistically significant difference with confidence intervals of 95 % in all tests.

Results

Eleven of the 13 patients admitted to our specialized unit during the study period were included. Of the 11 patients, 8 had traumatic brain injury, 2 had cerebral anoxia, and 1 had severe intra cranial hemorrhage. Two patients were not included because of previous pathologies namely a primary brain tumor, and cerebellar metastasis of lung adenocarcinoma.

Most patients included were male (9 patients, 81.8 %), and there were no women among the severe TBI. Eight (72.7 %) patients were right-handed. Table 1 describes the general characteristics of included patients. The average age at the time of severe brain injury was 40.7 $\pm$ 14.6 years with a median of 41 years [19–62]. Patients without TBI (patients 9, 10, and 11) tended to be older than patients with severe TBI (patients 1–8), each with an average age of 49.3 $\pm$ 8 years (median age 50 [41–57]) versus 37.5 $\pm$ 15.6 years (median 38.5 years [19–62]) ($p = 0.14$). Initial GCS was low (mean 5.3 $\pm$ 3.2; median 5 [3–13]). One patient with severe TBI (patient 2), with an initial trauma fracture involving the three levels of the face including the mandible, had a minor functional limitation of mouth opening, without limitation of range on motion during passive movements. Five other patients with severe TBI (patients 1, 4, 5, 7, and 8) had a fracture of the middle third of the face with no effect on mouth opening. Six patients had a fracture of one or more limbs and pulmonary contusions, and one patient had only pulmonary contusions. No patient with severe TBI had cervical spine or abdominal lesions.

During stay in ICU, the mean duration of orotracheal intubation was 27.5 $\pm$ 12.6 days (median 26 days [1–46]). Seven patients had a respiratory infection (patients 1, 3, 4, 6, 7, 8, and 10). Elevated ICP was observed in only 5 of the 7 (patients 1, 4, 7, 8, and 10). No patient had a brain ventricular shunt. None of the patients had swallowing speech therapy before admission to rehabilitation center.

The average time between severe brain injury and admission to rehabilitation center was 65.6 $\pm$ 25.8 days

Table 1 General characteristics of included patients

Patients	1	2	3	4	5	6	7	8	9	10	11
Severe brain injury											
Age (years)	43	54	62	19	39	20	38	25	50	41	51
Cerebral lesion cause	Severe TBI	Severe TBI	Severe TBI	Severe TBI	Severe TBI	Severe TBI	Severe TBI	Severe TBI	Cerebral anoxia	Intracranial hemorrhage	Cerebral anoxia
Lesional mechanism	Road accident	Farm accident	Unkown	Road accident	Road accident	Road accident	Road accident	Road accident	CPA	Ruptured cerebral aneurysm	CPA
Initial GCS (/15)	3	9	13	5	6	3	5	5	3	3	3
Intracranial lesions	Hemispherical	Hemispherical	Hemispherical	Hemispherical	Hemispherical	Hemispherical and cerebellar	Hemispherical	Hemispherical and brainstem	Hemispherical	Hemispherical	Cerebellar
	Focal* bilateral	Focal* unilateral and diffuse** (MH)	Focal* bilateral and diffuse** (DAL), herniation	Focal* bilateral	Focal* unilateral and diffuse** (MH)	Focal* unilateral Cerebral oedema	Focal* unilateral and diffuse** (MH), herniation	Focal* bilateral and diffuse** (DAL), cerebral oedema	Diffuse** (hypoxic lesions)	Focal* unilatéral cerebral oedema	Focal* bilatéral
On admission to rehabilitation center											
Time between severe brain injury and admission (days)	92	44	64	59	78	58	127	62	35	44	59
WHIM score (/62)	25	43	15	43	26	3	21	15	57	43	5
Tracheostomy	X	X	X	X	/	X	X	X	X	X	/
Cuff inflated	X	X	X	X	/	X	X	X	/	X	/
Bronchial congestion	/	/	X	/	/	/	X	X	/	/	/
BMI (kg/m^2)	18.5	24	30.4	21.5	22.3	15.7	17.8	16	26	26.8	25
Denutrition	/	Moderate	Severe	Severe	/	Moderate	Moderate	Severe	/	Severe	Severe
Enteral alimentation tube	Gastrostomy	Nasogastric	Gastrostomy	Gastrostomy	Gastrostomy	Gastrostomy	Gastrostomy	Gastrostomy	Gastrostomy	Gastrostomy	Gastrostomy
Can stare at	X	X	X	X	X	/	/	/	X	X	X
Can execute on request	/	X	/	/	X	/	/	/	X	X	X
Motor deficit of limbs	NE	Global, 4 limbs	NE	NE	Global, 4 limbs	Left hemiplegia	NE	NE	NE	Left hemiplegia	Global, 4 limbs
Sensory deficit of limbs	NE	/	NE	NE	NE	NE	NE	NE	/	NE	NE

Table 1 continued

Patients	1	2	3	4	5	6	7	8	9	10	11
Swallowing examination											
Drooling	/	/	/	/	/	/	/	X	X	/	/
Altered oral state	X	/	X	/	/	/	/	/	X	/	/
Eye movements	NE	Preserved	NE	preserved	NE	NE	NE	Unilateral defect	Unilateral defect	Preserved	NE
Achievement V nerve	NE	Preserved	NE	NE	NE	NE	NE	NE	Preserved	Preserved	NE
Achievement VII nerve	Unilateral PFP	Preserved	NE	Unilateral CFP	Unilateral CFP	NE	NE	NE	Unilateral CFP	Unilateral CFP	Preserved
Able to sit 30 min	/	X	/	X	X	/	/	/	X	X	X
Head straight	/	X	/	X	/	/	/	/	X	X	X
Coordinated movement	/	X	/	/	X	/	/	/	X	X	/
(hand to mouth, side)		Dominant side			Dominant side				Bilatéral	Dominant side	

BMI body mass index, *CFP* central facial paralysis, *CPA* cardiopulmonary arrest, *GCS* Glasgow Coma Score, *DAL* diffuse axonal lesions, *MH* meningeal hemorrhage, *NE* not evaluable, *PFP* peripheral facial paralysis, *TBI* traumatic brain injury, *WHIM* Wessex Head Injury Matrix, *X* observed, / not observed

* Focal intracranial lesions: contusion, extradural/subdural/intracerebral hematoma, edema, infarct, ischemic necrosis, abscess

** Diffuse intracranial lesions: axonal lesions, hypoxic/ischemic lesions, diffuse vascular lesions, fat emboli, subarachnoïd hemorrhage, meningitis

for a median 59 days [35–127]. The clinical characteristics of patients at admission are listed in Table 1. Four (36.4 %) patients were considered to be in a vegetative state according to WHIM, 6 patients (54.5 %) in a minimally conscious state, and 1 patient (9.1 %) in a confusional state. All patients were fed by enteral alimentation tube. None of the nine patients with a tracheostomy had a phonatory valve or a closed tracheostomy tube. All but one patient (patient 6) had a limitation of range of motion of the upper limbs.

The first clinical evaluation of swallowing occurred within an average of 3.6 ± 2.8 days (median 3 days [1–8]) after admission to our specialized rehabilitation unit, and 69.3 ± 26.3 days (median 61 days [36–131]) after severe brain injury, but none of the patients met all the prerequisites for the swallowing test. Nevertheless, there was no evidence of motor or sensory impairment of cranial nerves either by clinical examination or by nasal endoscopy which demonstrated velopalatine and lingual hypotonia. The first clinical functional swallowing test was performed within an average of 23.8 ± 31.3 days (median 7 days [1–95]) after admission to our specialized rehabilitation unit and 83 ± 43.3 days (median 73 days [35–183]) after severe brain injury. Data on clinical status during the functional swallowing test are displayed in Table 2. Data are missing for two patients with severe TBI (patients 3 and 7) because of major alteration of airway protection mechanisms with high risk of aspirations, which is the reason why they were unable to undergo swallowing tests. Patient 10 had intermittent reflex coughing during spontaneous swallowing at first swallowing test, suggesting probable intermittent salivary aspiration. Patient 10 was clinically evaluated every week until intermittent reflex coughing had stopped before undergoing the functional swallowing test. None of the first swallowing tests was completed. It was sometimes difficult (patients 4, 6, and 10) or impossible (patient 10) to perform due to refusal or lack of patient cooperation. Moreover, the test was prematurely stopped for 2 patients with severe TBI (patients 4 and 8) because of significant oral residues leading to a major risk of aspirations. With compote consistency, there were mainly bolus transport disorders involving oral and pharyngeal transport in 77.8 and 66.7 %, respectively. Conversely, with sparkling water, alterations in airway protection mechanisms were predominant and concerned 80 % of tested patients.

Nasal endoscopy was performed within an average of 14.8 ± 11.9 days (median 11 days [4–48]) after admission to our specialized rehabilitation unit, and 80.4 ± 30.1 days (median 70 days [46–144]) after severe brain injury. Out of the 11 patients included, 1 with severe TBI (patient 4) had no endoscopic evaluation, due to rejection and motor restlessness. For the other 10 patients, the results of the endoscopic swallowing test are reported in Table 3. Only five patients were able to execute a movement on request. The remaining six patients were checked by searching for spontaneous or provoked movements. We were unable to reach a conclusion for three of them, and we did not observe impaired cranial nerves for the other three.

A total of 7 (63.6 %) severe brain injured patients were able to resume oral feeding during the study, 6 of whom (54.5 %) resumed full oral feeds including 5 patients (patients 2, 4, 6, 9, 10) with FOIS 5 and 1 patient (patient 1) with FOIS 3. Only 1 of the 7 severe brain injured patients (patient 5) had resumed oral feeding without adapted textures (FOIS 7) on discharge at 62 days. The period of oral food recovery with modified solid and liquid texture averaged 44 ± 37 days (median 41 days [12–122]) after admission to our specialized rehabilitation unit and

Table 2 Clinical conditions during first functional swallowing test

Patient	Time since severe brain injury (days)	WHIM score (/62)	Attention (<15 min)	Voluntary cough	Voluntary throat clearing	Spontaneous salivary swallowing without cough or desaturation	Respiratory infection	Swallowing		
								On request	Drooling	Wet voice
1	183	46**				X				
2[a]	44	43**	X	X	X					
4[a]	59	43**				X				No vocalisation
5[a]	73	26**	X					X		
6	93	4*	X					X		No vocalisation
8	98	31**				X				No vocalisation
9[a]	35	57***	X	X	X			X		No vocalisation
10[a]	72	58***	X					X		
11[a]	90	5*				X				No vocalisation

NE not evaluable, *WHIM* Wessex Head Injury Matrix, *X* observed

[a] First functional swallowing test performed at first assessment on admission

* Vegetative state, ** Minimally conscious state, *** Confusion after coma

Table 3 Results of swallowing test under endoscopic control

Patient	Salivary stasis	Salivary aspirations		Swallowing test with compote texture			Swallowing test with liquid mint		
		With cough	Without cough	Coordination disorder	Aspiration	Pharyngeal residue	Coordination disorder	Aspiration	Pharyngeal residue
1	X		X	Untested	Untested	Untested	Untested	Untested	Untested
2	X		X	Unobserved	Unobserved	X	Untested	Untested	Untested
3	X		X	Untested	Untested	Untested	Untested	Untested	Untested
4	NE	NE	NE	NE	NE	NE	NE	NE	NE
5				X, moderate	Unobserved	Unobserved	X, moderate	Unobserved	Unobserved
6				X, important	Unobserved	Unobserved	X, important	X	Unobserved
7	X		X	Untested	Untested	Untested	Untested	Untested	Untested
8	X		X	X, important	X	Unobserved	Untested	Untested	Untested
9				Unobserved	Unobserved	Unobserved	Untested	Untested	Untested
10				X, important	Unobserved	Unobserved	X, important	Unobserved	Unobserved
11				X, important	X	Unobserved	X, important	X	Unobserved

NE not evaluable, *X* observed

98.3 ± 53.3 days (median 83 days [47–210]) after severe brain injury. Enteral feeding was interrupted at an average of 62.1 ± 43.8 days (median 51 days [32–157]) after admission to our specialized rehabilitation unit and 120.7 ± 59.2 days (median 109 days [71–249]) after severe brain injury. Exclusive enteral feeding (FOIS 1) was maintained for 3 patients (patients 3, 7 and 11). Enteral nutrition was maintained for the third (patient 11) because of the discovery of a distal esophageal stricture. The other 2 patients met none of the prerequisites for the functional swallowing test, and silent aspirations were observed during nasal fiberscopy, indicating a major alteration of airway protection mechanisms.

Our secondary objective was to compare the initial clinical characteristics of patients with severe TBI having resumed oral feeding and patients unable to resume oral feeding 3 months after admission to our specialized rehabilitation unit. Of the 8 patients with severe TBI, 4 (50 %) (patients 2, 4, 5, and 6) resumed oral feeding at 3 months from the first assessment on admission to our specialized rehabilitation unit. The mean time to oral refeeding was 29.2 ± 16.8 days (median 29 days [11–48]) after admission to our specialized rehabilitation unit and 113.2 ± 56.5 days (median 102 days [65–210]) after severe brain injury. No significant difference was demonstrated between the two patient groups with regard to baseline clinical characteristics. However, all patients with severe TBI, who did not resume oral feeding, had a tracheostomy tube with inflated cuff at admission, unlike patients fed by mouth ($p = 0.14$). Patients unable to return to oral diet also seemed to have more frequent bronchial obstruction ($p = 0.14$). Comparison of neurological findings on swallowing between the two groups was not contributory due to a significant number of nonevaluable data. Nasal endoscopy highlighted the salivary stasis and aspirations in all patients unable to return to oral diet. None of these patients were able to undergo a swallowing test under endoscopic control, compared to only one patient who resumed oral feeding ($p = 0.14$). Finally, patients with severe TBI who resumed oral feeding were all weaned off tracheostomy tube during their stay, compared to only one patient who did not return to an oral diet ($p = 0.14$).

Discussion

This is the first study to our knowledge, to focus on the clinical characteristics of swallowing, at the bedside of patients with severe brain injury, during the arousal phase after coma. All causes were included. Our main results are that swallowing disorders are often oral and pharyngeal transport disorders of food bolus with compote consistency, and impaired airway protection mechanisms with liquid consistencies.

In our sample, swallowing disorders were more frequent at admission [2, 39], with a lower proportion of oral refeeding [2, 24, 40] and a longer duration [2, 39, 40] than in the literature. Indeed, all severe brain injured patients included in our study had swallowing disorders, 63.6 % of patients resumed oral feeding within an average of 44 days and only 1 of our patients (9.1 %) recovered total oral feeding with normal consistency within an average of 62 days. One hypothesis to explain the differences between our results and those in the literature is the fact that the level of consciousness and cognitive functioning of patients described in previous studies [2, 24, 39, 40] was higher than that in ours, which

included a majority of patients in a vegetative or minimally conscious state. Furthermore, Winstein et al. [24] and Mackay et al. [39] considered low level of arousal to be a negative predictor of oral refeeding, which was later confirmed by Hansen et al. [2] and Terré et al. [6]. Nevertheless, caution is required when comparing our results with those in the literature. Indeed, the data from the above studies selectively concern TBI patients regardless of severity [2, 39] or level of intensity [24, 40]. Moreover, time of treatment varied between acute phase [39, 40], post-acute care unit [2], and rehabilitation unit specializing in post-trauma care of TBI [24]. It is important to state clearly when evaluation was performed since oral and pharyngeal functions improve and aspirations decrease after severe TBI particularly between 3 and 6 months of evolution [6].

We have highlighted several potentially negative predictive factors for oral refeeding, at 3 months after admission, in patients with severe TBI. These factors include a tracheotomy with inflated cuff and bronchial congestion at admission, salivary stasis, and aspirations observed during nasal endoscopy, and not being weaned off the tracheostomy tube during hospital stay. The factors we identified are distinct from those found in the literature; higher age at time of traumatic injury [41], initial GCS <6 [2, 39], mechanical ventilation exceeding 2 weeks [39], lower level of cognitive functioning [2, 6, 24, 39, 41], tracheostomy at admission [39–41], motor disabilities at admission [24], low level of functional independence at admission [2], and aphonia [41]. In addition, Terré et al. [6] pointed out that patients who had at baseline a Ranchos Los Amigos Level Cognitive Function (RLCF [42]) III (localized response) and a disability rating scale (DRS [43]) 20 (SD 0.75) still showed aspirations at 1 year, while patients without aspiration had RLFC > IV (confused, agitated response) and DRS 16 (SD 4.6). We could improve the detection of correlations in our study by increasing the size of our sample to improve statistical power and by means of RLCF and DRS to evaluate cognitive and functional impairments. According to the literature, positive predictive factors for oral refeeding are a short average length of stay in ICU (80 % likelihood of recovering oral feeding for a length of stay <7 days, and 56 % for <24 days), and exclusive oral feeding or adapted oral feeding at admission to rehabilitation center [2].

Our bedside swallowing assessment protocol combining clinical examination and nasal endoscopic examination, functional swallowing test, and swallowing test under endoscopic control is feasible, simple, fast, and safe. Indeed, clinical assessment and endoscopic assessment lasted about 15 min each. All tests were proposed to all patients included. There were no complications related to swallowing disorders, such as weight loss or respiratory infection, neither after the functional swallowing test, nor the swallowing test under endoscopic control, nor resumption of oral feeding. In addition, the first bedside swallowing test was achieved within a period of 1 week after admission to our specialized rehabilitation unit. Early evaluation is a major benefit of the proposed method. Indeed, Ward et al. [40] showed that advancing the deadline for first bedside evaluation of swallowing by 1 day, increased the potential for recovery of oral feeding between 11 and 15 % related to normal texture oral feeding.

However, current clinical prerequisites for functional swallowing test do not seem suited to patients in arousal phase after coma since patients' attention span does not generally exceed 15 min. In addition, most of our patients were unable to vocalize or perform reproducible voluntary coughing, throat clearing, or salivary swallowing. Thus, as a complement to our protocol, it appears necessary to propose other relevant clinical criteria. Repeated spontaneous swallowing of saliva without coughing or more than 3 % desaturation measured by pulse oximeter would indicate immediate implementation of the swallowing test. Conversely, test contraindications would include drooling, coughing, throat clearing, more than 3 % desaturation measured by pulse oximeter, wet voice observed during spontaneous swallowing of saliva, and desaturation over 3 % without cough reflex and with or without observed swallowing. The criteria proposed above require validation in a large prospective randomized study.

The inclusion of a nasal endoscopic examination in swallowing evaluation protocol seems relevant and may provide additional information to neurological examination. Indeed, it is difficult to confirm the functional integrity of pairs of cranial nerves (IX, X, XII) in patients in arousal phase after coma, due to a lack or fluctuation in motor response upon request [30]. Moreover, unlike physical examination, endoscopic examination with swallowing test will highlight not only direct silent aspirations [36], but also a delay or the absence of pharyngeal swallowing reflex [38]. This latter reflects impaired swallowing coordination. Furthermore, digital endoscopy images could be looked at in real time and as many times as necessary with slow motion sequences to strengthen the detection of swallowing disorders. Finally, the feasibility and utility of nasal endoscopy and swallowing test, at post acute phase of TBI, have already been demonstrated in the literature [37].

Although our study was prospective and consecutively included all patients with severe brain injury admitted to rehabilitation center, it has several limitations. First, the number included was low, implying low statistical power. Second, the multiple causes of severe brain injury may limit extrapolation of our results to all patients with severe brain injuries. However, the swallowing disorders observed in our sample involved severe TBI, with cerebral anoxia

either after cardiopulmonary arrest or after intracerebral hemorrhage in ruptured cerebral aneurysm. Furthermore, since there was no set time for the swallowing test, assessment was often performed outside of enteral dietary administration. In future studies, this evaluation will be administered at meal times, especially during lunch when patients are awake. This would help to restore patients' circadian rhythm and daily organization. Finally, videofluoroscopy, which is the gold standard for evaluation of swallowing disorders [19], was not used in our study since it entails rigorous assessment conditions [44] which were difficult to apply reliably and safely in routine practice in our easily tiring patients.

To conclude, our findings show that oral and pharyngeal transport disorders often involve compote consistency, and impaired airway protection mechanisms involve liquid consistencies. Nevertheless, it is still necessary to confirm these results in future studies with larger samples of patients with severe brain injuries in the arousal phase after coma. Furthermore, we recommend that the assessment and management of swallowing disorders should be included in the overall and multidisciplinary medical and rehabilitation treatment of patients with severe brain injuries during the arousal phase after coma. Swallowing disorders are a major complication in severe brain injury in the arousal phase. As a result, early bedside assessment of swallowing is essential for detection of swallowing disorders to propose appropriate medical rehabilitation care to these patients in a state of altered consciousness.

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Compliance with Ethical Standards

Conflict of interest The authors declare there is no conflict of interest that may be inherent to the submission of this work.

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