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REVIEW

Links Between Swallowing and Consciousness: A Narrative Review

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Abstract
This literature review explores a wide range of themes addressing the links between swallowing and consciousness. Signs of consciousness are historically based on the principle of differentiating reflexive from volitional behaviors. We show that the sequencing of the components of swallowing falls on a continuum of voluntary to reflex behaviors and we describe several types of volitional and non-volitional swallowing tasks. The frequency, speed of initiation of the swallowing reflex, efficacy of the pharyngeal phase of swallowing and coordination between respiration and swallowing are influenced by the level of consciousness during non-pathological modifications of consciousness such as sleep and general anesthesia. In patients with severe brain injury, the level of consciousness is associated with several components related to swallowing, such as the possibility of extubation, risk of pneumonia, type of feeding or components directly related to swallowing such as oral or pharyngeal abnormalities. Based on our theoretical and empirical analysis, the efficacy of the oral phase and the ability to receive exclusive oral feeding seem to be the most robust signs of consciousness related to swallowing in patients with disorders of consciousness. Components of the pharyngeal phase (in terms of abilities of saliva management) and evoked cough may be influenced by consciousness, but further studies are necessary to determine if they constitute signs of consciousness as such or only cortically mediated behaviors. This review also highlights the critical lack of tools and techniques to assess and treat dysphagia in patients with disorders of consciousness.

Keywords Dysphagia · Swallowing · Severe brain injury · Disorders of consciousness · Consciousness · Coma

Introduction

In healthy individuals, swallowing is such an automated sensorimotor mechanism that, apart from episodes of food "going down the wrong way" due to distraction, no one consciously experiences their swallowing. An exception exists with mindfulness and we can consciously experience our swallowing if we decide to voluntarily pay attention to it. Depending on the disease, the prevalence of dysphagia can be very high in neurological populations [1–5] and different components of the swallowing sequence can be affected. In acquired brain injury, we can reasonably assume that, the more severe the brain injury, the more severe the dysphagia [6, 7]. The severity of brain injury is classically defined, among other things, according to the Glasgow Coma Scale (GCS) [8], on admission and coma duration [9]. The question of what factors (e.g., lesion localization and volume, type of brain injury, consciousness) most affect the severity of dysphagia following brain injury has not yet been completely elucidated.

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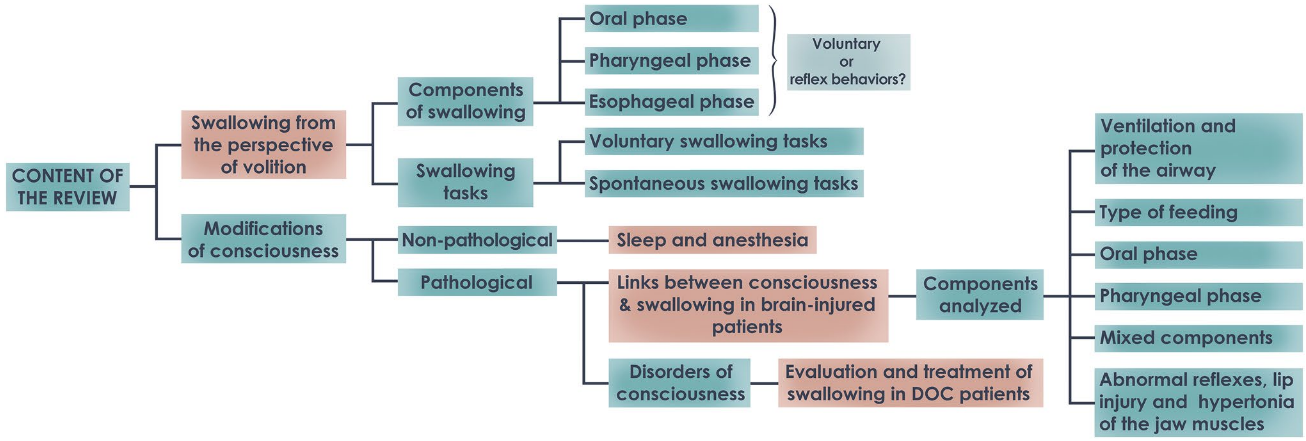

Fig. 1 Summary of the research fields explored in this review. Orange rectangles indicate the main fields covered by the literature review. *DoC* disorders of consciousness

Consciousness is a complex phenomenon. In the field of clinical science, researchers define consciousness based on two components: wakefulness (arousal) and awareness (subjective experience) [10]. Consciousness allows us to be aware of objects and events, inside and outside our body [10, 11]. Wakefulness and awareness are generally correlated. Although healthy people are aware when they are awake, during coma and in most cases during general anesthesia, patients are neither awake nor aware. Modifications of consciousness can be pathological (disorders of consciousness) or non-pathological (sleep or anesthesia).

Disorders of consciousness (DoC) represent different states along a continuum from coma (no arousal and no awareness) to being conscious and awake (preserved arousal and awareness). Between the two extremes, unresponsive wakefulness syndrome (UWS, previously termed vegetative state) is defined by recovery of arousal in the absence of any sign of awareness [12], whereas minimally conscious state (MCS) refers to preserved arousal and reproducible but inconsistent signs of consciousness [13]. The MCS entity can be subdivided into minimally conscious state MINUS (MCS−) and PLUS (MCS+) based on the presence (MCS+) or absence (MCS−) of behaviors indicating at least partial preservation of language abilities [14, 15]. When patients recover the ability to functionally communicate or to use two objects appropriately, we consider that they are emerging from the minimally conscious state (EMCS) [13]. Patients with locked-in syndrome (LIS) have woken from their coma and are fully conscious but are unable to show behavioral signs of consciousness except by eye movements [16]. UWS and MCS are usually transitional states between coma and higher levels of consciousness. However, some patients present prolonged, chronic DoC.

Misdiagnosis can have serious medical and ethical consequences for patients and their families. Indeed, functional outcomes and prognoses are better for MCS than UWS [17, 18]. Moreover, response to treatment seems to be better in patients in MCS [19]. Regarding pain management, noxious stimuli seem to elicit a larger cerebral response in patients in MCS than with UWS, suggesting that patients in MCS may be more likely to feel pain than those with UWS [20–22]. Finally, level of consciousness influences end-of-life decisions [23, 24].

Recent guidelines for the diagnosis of patients with DoC recommend that one use valid, reliable standardized neurobehavioral assessments of consciousness [25–27]. The Coma Recovery Scale–Revised (CRS-R) is the reference standard for the clinical bedside evaluation of consciousness [28], as it fulfills all the Aspen Neurobehavioral Workgroup criteria [29]. The diagnostic criteria for consciousness in the CRS-R are classified in six categories (auditory, visual, motor, oromotor/verbal, communication, arousal). Beyond behaviors assessed using the CRS-R, some authors have identified other criteria linked to level of consciousness [30, 31] and other possible signs of consciousness [32–35].

Level of consciousness has an impact on a variety of abilities such as language [36], motor function [37], sphincter function [38] and feeding [39]. Most patients with DoC are fed by enteral feeding tube [40, 41]. However, the true impact of consciousness on swallowing abilities remains poorly understood. It is relatively clear to therapists working in dysphagia rehabilitation that level of consciousness influences swallowing abilities. However, the links between swallowing and consciousness have not yet been examined to any great extent.

Because of the scarcity of studies directly related to swallowing and consciousness, in this review we chose to explore a wide range of themes addressing the links between swallowing and consciousness rather than focusing on one topic or answering one specific question (see Fig. 1).

Section 1: Swallowing from the Perspective of Volition

The approach historically used to determine whether or not a patient is conscious consists in the comparison of reflexive and voluntary behaviors [13]. However, the difference between conscious and reflexive behaviors remains ambiguous [42]. In fact, there are no empirical characteristics that allow us to reliably distinguish reflexive behaviors from conscious behaviors [42].

Prochazka et al. [43] demonstrated that the distinction between *voluntary and reflex* differs depending on the approach. The Prochazka/Loeb/Rothwell position [43] describes voluntary behaviors as those that proceed under conscious control (Loeb) and that we can interrupt, influence (Rothwell) and suppress at will (Prochazka) and reflex behaviors as those that are automatic and hard to suppress (Prochazka) and that cannot be modified voluntarily. Some researchers [44, 45] also agree that all voluntary behaviors contain automatic processes contributing to their rapidity and flexibility. Moreover, two types of reflexes are involved in swallowing: somatic and autonomic reflexes (see below) [46]. Somatic reflexes implicate striated/skeletal muscles, and autonomic reflexes target smooth muscles.

Based on these characteristics (see Table 1), we will analyze the different components of swallowing and try to distinguish voluntary from reflex behavior.

Components of Swallowing

Swallowing is divided into three phases (oral, pharyngeal, esophageal), each one comprising several components. The oral phase is classically described as the voluntary phase of swallowing while the pharyngeal and esophageal phases are the reflexive phases [47]. To confirm this assumption, we will now discuss the different components in each phase of swallowing in light of the characteristics of voluntary versus reflex behaviors (Fig. 2).

Oral Phase

Although we chew and transport food without consciously controlling each orofacial movement, the oral phase is the only phase of swallowing that can be entirely interrupted and consciously controlled. In that respect, the modifiable and suppressible character of the oral phase categorizes this phase as voluntary behavior. In addition, several studies have demonstrated that consciously controlling the oral phase modifies its sequencing [48–50]. Indeed, the chewing sequence can be significantly lengthened (almost twice as long) with volition (e.g., chewing with a conscious effort, or a specific number of chews) than without volition (i.e., eating normally). These data emphasize the role of automatic processes in natural feeding conditions. In other words, most of the time, the various lip and tongue movements occur without volition but rather as semiautomatic periodic or rhythmic movements, which explains why, in "controlled" conditions, the oral phase lasts longer.

The notion of semiautomatic periodic or rhythmic movements is not recent [51]. Many studies, especially those by Sessle's team [52–55], have explored the neural control of orofacial movements in primates using intracortical microstimulations. They indicated that the primary motor cortex dedicated to the orofacial area is involved in voluntary movements but also in the control of semiautomatic movements, such as tongue and mastication movements. Studies of oral reflexes also showed that diffuse stimuli to the palate in decerebrated and anesthetized cats elicited rhythmic tongue activity [56]. Moreover, in the field of epilepsy, one study showed that electrical stimulation of the right inferior frontal gyrus (fronto-opercular cortex) leads to oroalimentary automatisms (lip movements, chewing) [57].

The oral phase of swallowing can be classified as a voluntary behavior but, like any another motor activity, it includes some automatic processes. As described by Humbert and German [58], during feeding, the different components of the oral phase can moved along the continuum of low to high voluntary control depending on the degree of attention dedicated specifically to them. The pattern-generating circuits for chewing and licking are located in the brainstem but receive direct cortical inputs [59].

Table 1 Characteristics of voluntary behavior and somatic and autonomic reflexes

	Voluntary behavior	Somatic reflex	Autonomic reflex
Type of peripheral efferent nervous system	Somatic nervous system	Somatic nervous system	Autonomic nervous system
Characteristics	Under conscious control Can be interrupted Can be influenced Can be suppressed at will	? Cannot be interrupted Can be influenced to some degree Hard to suppress	Not conscious Cannot be interrupted Cannot be influenced Cannot be suppressed
Type of muscles	Striated/skeletal muscles	Striated/skeletal muscles	Smooth muscles

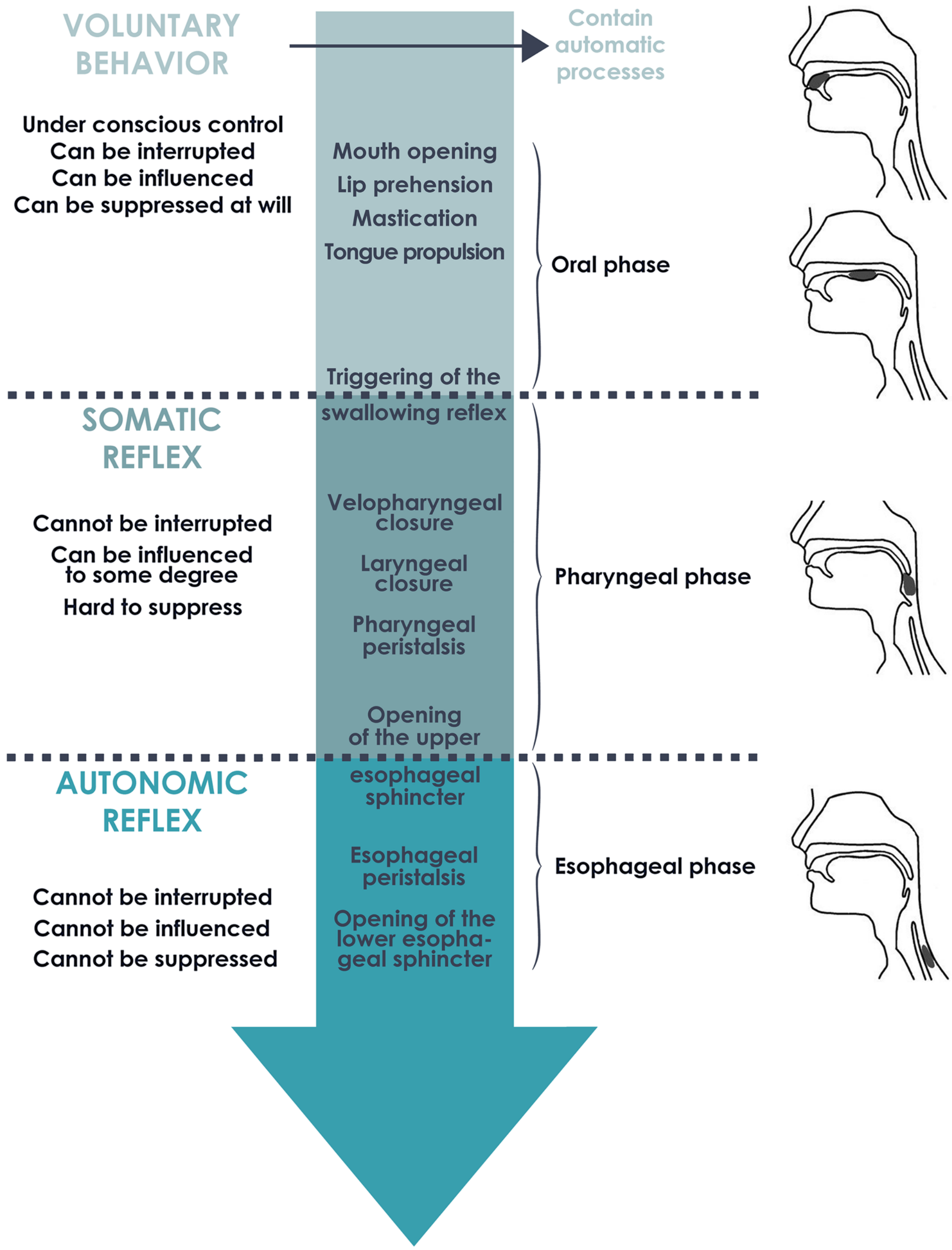

Fig. 2 Classification of the oral, pharyngeal and esophageal phases of swallowing on the continuum of voluntary to reflexive behaviors

Pharyngeal Phase

The triggering of what is commonly called the "swallowing reflex" heralds the end of the oral phase and the beginning of the pharyngeal phase. This reflex is a somatic reflex because it involves striated/skeletal muscles.

In "natural" conditions, the swallowing reflex occurs in response to saliva accumulation or to the presence of liquid or food in the oropharyngeal space (i.e., area of the soft palate, faucial pillars, pharyngeal surface of the epiglottis, dorsal pharyngeal wall). Indeed, when a sensory input (presence of saliva or a liquid or solid bolus) reaches a certain threshold, it triggers the swallowing reflex, which elicits the start of the sequence leading to protection of the airway and transportation of the bolus to the esophagus [60]. The timing of the initiation of the swallowing reflex is influenced by the waking state (see Sect. 2), type of bolus (shortest with liquids) [61] and cognitive functions [62–64].

Although the swallowing reflex is usually triggered without conscious perception, it can be evoked voluntarily. Moreover, the swallowing reflex can be artificially initiated in humans by air pulses [65] or electrical stimulations [66, 67] of the pharyngeal area. Whereas the execution of the oral phase can be stopped at any time, the swallowing reflex is hard to suppress for a long time during feeding or at rest.

If we refer to the definitions of Prochazka et al. [43], the swallowing reflex can be triggered voluntarily but is usually automatic and is hard to suppress. It is thus on the borderline between a voluntary behavior and a reflex. Moreover, we can postulate that the transition between a voluntary behavior and a somatic reflex takes place somewhere between the beginning of the stage II oral phase transport and the triggering of the swallowing reflex.

On the other hand, the proceedings occurring after the trigger of the swallowing reflex (pharyngeal phase) cannot be suppressed voluntarily, unlike the oral phase and, to a lesser extent, the triggering of the swallowing reflex. However, some studies have shown that the pharyngeal phase can be influenced voluntarily to some extent; for example, patients can learn maneuvers that change swallowing physiology and help to reduce aspirations (e.g., Mendelsohn maneuver or effortful swallow) [58, 68, 69]. The process of the pharyngeal phase is mainly a somatic reflex.

Esophageal Phase

The opening of the upper esophageal sphincter (UES) marks the end of the pharyngeal phase and the start of the esophageal phase. The UES is also called the inferior pharyngeal sphincter [68]. Muscles involved in the upper third of the esophagus (mainly the UES) are striated muscles under the control of vagal cholinergic motoneurons in the nucleus ambiguus of the brainstem (partly with the vagus cranial nerve X). In the lower two-thirds of the esophagus, which is composed of smooth muscles, neural control switches to the autonomic/vegetative (enteric) nervous system through motoneurons situated in the ganglia [68, 70–72].

The esophageal phase cannot be voluntarily triggered or suppressed. The only influence on the esophageal phase is a passive or active effect on the UES. In fact, Shaker et al. [73] showed that head-raising exercises improve the UES, among other things. The mechanism at play is a passive stretch of the UES and/or an improvement of pharynx propulsion, which facilitates the opening of the UES. More recently, Winiker et al. demonstrated that volitional modulation of the pressure in the region of the UES (active effect) is also possible in healthy subjects after training using visual biofeedback exercises [74]. For these reasons and given anatomical considerations [75], we can assume that the transition between a somatic and an autonomic reflex (and consequently between striated and smooth muscles) takes place somewhere in the upper third of the esophagus.

Swallowing Tasks

In the last 20 years, several researchers have explored the different stages of swallowing in healthy participants and in patients with dysphagia. Swallowing has been studied in several conditions (saliva, liquid or food swallowing) and, in addition to the voluntary or reflexive nature of each component of swallowing, some authors also distinguish swallowing tasks depending on the influence of volition.

Ertekin et al. [76] distinguished between reflexive swallows (water introduced to the back of the tongue with a syringe), nasopharyngeal swallows (water introduced through a canula at the level of the uvula), spontaneous swallows (accumulation of saliva in the mouth that triggered spontaneous swallowing) and voluntary swallows (1–3 mL of water swallowed voluntarily) in an electrophysiological study. They showed, among other things, that the time interval between the onset of submental EMG and the onset of upward deflection of the larynx was significantly shorter for reflexive, nasopharyngeal and spontaneous swallows than for voluntary swallows. Kern et al. [77] compared reflexive (rapid injection of water into the pharynx) and voluntary swallows (cued to swallow saliva volitionally once every 30 s by a tactile cue) in a neuroimaging study. While reflexive swallowing was associated with bilateral activity concentrated in the primary sensory/motor regions, volitional swallowing was represented bilaterally in the insula, prefrontal, cingulate, and parieto-occipital regions in addition to the primary sensory/motor cortex.

One decade later, Ertekin [78] dedicated a literature review to a comparison of spontaneous swallowing and voluntary swallowing. He described spontaneous swallowing as a "type of protective reflex action that occurs to ensure safety of the upper airway tract against any escape of food particles or saliva, or as an emotion-related reflex activity occurring during stressful conditions" (2011, p. 184). Spontaneous swallowing occurs without awareness while one is awake or asleep. The oral phase is bypassed in most cases, although there may be partial excitation. Spontaneous swallowing is also sometimes called "reflexive swallowing" or "non-nutritive swallowing." On the other hand, he described voluntary swallowing (also called "conscious swallowing") as sequential eating or drinking voluntarily initiated or facilitated by the cerebral cortex during the awake and aware state [78].

In Table 2, we describe several types of volitional (VOST) and non-volitional swallowing tasks (NVOST) related to the concept of reflexive (RS), spontaneous (SS) and voluntary swallowing (VS). Because of the potentially different brain activations and different physiological mechanisms at play during nutritive compared to non-nutritive swallowing, we also make a distinction between these two types of swallowing tasks. Reflexive swallowing refers to triggering of the swallowing reflex by an external stimulus (tactile or with the injection of a bolus). In this case, the participation of the oral phase is diminished but not completely bypassed considering the involvement of the tongue in any swallowing process. Non-nutritive spontaneous swallowing refers to the management of saliva and secretions that are produced spontaneously by all healthy humans, while nutritive spontaneous swallowing is associated with eating and drinking. Volitional swallowing tasks refer to tasks occurring further to an internal or external request.

Section 2: Non-pathological Modifications of Consciousness: Sleep and Anesthesia

Investigating swallowing in non-pathological modifications of consciousness such as sleep or anesthesia allows to explore swallowing without the ambiguity of conscious control. Indeed, sleep and anesthesia are associated with reduced consciousness and lack of volition, enabling volitional versus non-volitional swallowing to be distinguished.

Sleep is classically divided into three stages of nonrapid eye movement (NREM) sleep (N1, N2 and N3) and rapid eye movement (REM) sleep. As described by Sanders et al. [79], in NREM sleep individuals are generally considered unconscious, disconnected and not responsive, but people recall dreams after being woken from NREM sleep in 23 to 74% of cases. In contrast, during REM sleep, individuals are sometimes considered conscious (in approximately 80% of REM sleep awakenings) and report vivid dreams, but they do not experience their environment. They are disconnected and not responsive.

During sleep and in the case of DoC, the absence of consciousness does not lead to a complete absence of swallowing. Several studies have explored spontaneous saliva swallowing in healthy adults during sleep [80–87]. During sleep, swallowing is episodic, absent for long periods and influenced by sleep stage [85–87]. The deeper the sleep stage, the lower the mean swallowing frequency. Swallowing occurs almost in association with movement arousals in both REM and NREM sleep [82, 86, 87]. Some authors reported no [86] or very few [87] swallows during deep sleep (NREM stage N3). Regarding the efficacy of the pharyngeal phase, healthy adults have lower velopharyngeal and hypopharyngeal swallowing pressures when asleep [80]. In their study, Kelly et al. [81] showed that breathing-swallowing coordination differed between volitional (saliva swallowing on command) and non-volitional swallowing (spontaneous saliva swallowing without cuing) conditions but not between their two non-volitional conditions (spontaneous saliva swallowing during waking and sleep). Moreover, during a functional test (instillation of water in the pharynx), more aspirations after swallowing were observed during sleep than during wakefulness, as well as more repetitive swallowing and coughing after swallowing [83].

Patients with neurological impairments (cerebral atrophy or lacunar infarct) demonstrated a delayed response between the delivery of water in the pharynx and the triggering of swallowing when asleep, compared to when awake, while the healthy group showed no significant difference between wakefulness and sleep [88]. In Parkinson's disease patients, the mean duration of sleep decreases while the number of spontaneous saliva swallowing increases compared to healthy subjects [89]. Moreover, patients present more multiple swallows than healthy subjects.

Anesthesia can also be considered as a way of exploring consciousness but cannot be considered simply as an "absence of consciousness" [90]. Different consciousness states can be observed during general anesthesia, depending on the anesthetic agent and dose: (1) a complete absence of subjective experience (unconsciousness); (2) conscious experience without perception of the environment (disconnected consciousness, as in dreaming); or (3) episodes of oriented consciousness with awareness of the environment (connected consciousness) [90].

Some authors [91–95] have shown that general anesthetics (e.g., propofol, sevoflurane, ketamine, midazolam), which generally cause some form of unconsciousness [79], can alter swallowing. Thus, during general anesthesia, the frequency of spontaneous saliva swallowing decreases and the number of pathological swallows (characterized by inspiration or followed by an inspiration) increases [91]. Moreover, studies analyzing the efficacy of swallowing after the injection of a liquid at the back of the tongue or the pharynx during anesthesia showed that the latency between the injection and the initiation of the swallowing reflex [92, 94, 96], and the number of aspirations [93] increase while laryngeal reflexes are depressed [95]. Moreover, coordination between respiration and swallowing can change with deep sedation or during the recovery period from general anesthesia [97, 98].

Table 2 Description of the different types of swallowing tasks

	Non-volitional tasks (NVOST)		Volitional tasks (VOST)
	Reflexive swallowing (RS)	Spontaneous swallowing (SS)	Voluntary swallowing (VS)
Non-nutritive	Triggering of the swallowing reflex with tactile stimulation in the pharyngo-laryngeal area	Saliva swallowing without visual or verbal instruction to swallow	Saliva swallowing under visual or verbal instruction to swallow
Nutritive	Injection of small amounts of water or food directly into the pharynx	Swallowing of water or food without visual or verbal instruction to swallow	Swallowing of water or food with visual or verbal instruction to swallow

All this information shows that the frequency, speed of initiation of the swallowing reflex, efficacy of the pharyngeal phase of swallowing (mainly the number of aspirations) and coordination between respiration and swallowing are influenced by the level of consciousness during sleep and general anesthesia.

In the next section, we will see how consciousness affects swallowing in patients with brain injuries.

Section 3: Links Between Consciousness and Swallowing in Brain-Injured Patients

The prevalence of dysphagia after severe brain injury is very high [41], mainly due to the large number of brain areas dedicated to swallowing (see above), any of which can be severely damaged by a brain injury. A large majority of patients with DoC require artificially delivered hydration and nutrition, mainly through a gastrostomy feeding tube [41, 99]. The aim of this section is to examine the extent, variety and characteristics of swallowing disabilities in patients with acquired brain injury (ABI), and identify which swallowing components are related to consciousness. To better understand these links, we reviewed and synthetized studies analyzing swallowing in relation to consciousness level (see supp mat 1 for search strategy and selected criteria). We found 18 studies that describe a link between consciousness and swallowing abilities (see Table 3 for characteristics and detailed results of the studies and Table 4 for a summary). Nine studies explored swallowing abilities for all etiologies [39–41, 100–105], while nine focused solely on traumatic brain injury (TBI) [7, 106–113].

Regarding the scale used to assess the level of consciousness, twelve studies reported the results of swallowing in patients diagnosed with the *Rancho Los Amigos (RLA) Scale* [114], four with *the Coma Recovery Scale—Revised (CRS-R)* [28], one with the *Sensory Modality Assessment and Rehabilitation Technique* (*SMART*) [115], one with the *Wessex Head Injury Matrix* (*WHIM*) [116] and one with the *Full Outline of UnResponsiveness* (*FOUR*) [117] (see supp mat 2 for description of scales).

The current literature shows some links between swallowing and consciousness in patients with ABI. However, the heterogeneity of the swallowing-related components described, the level of consciousness considered, the various study designs and the lack of clear diagnoses of DoC in a large majority of studies mean that we must be cautious when interpreting the results. In patients with severe brain injury, the level of consciousness is associated with several components related to swallowing, such as the possibility of extubation, risk of pneumonia, type of feeding or components directly related to swallowing such as oral or pharyngeal abnormalities.

Only four studies analyzed swallowing-related components specifically in patients with DoC diagnosed with a validated repeated behavioral scale [40, 41, 102, 105]. Both oral and pharyngeal phases of swallowing can be impaired in patients with DoC.

We identify a strong link between the oral phase of swallowing and level of consciousness [40, 41, 105]. Indeed, we did not detect an effective oral phase of swallowing (lip prehension, tongue propulsion and no post-swallowing oral stasis) in any of the patients with UWS [40, 41], and in only a small minority of those in MCS [40, 41, 105]. This also helped to explain why no patients with UWS were able to achieve full oral feeding and why only a small proportion of the patients in MCS could safely resume full oral feeding with easy-to-swallow food [40, 41]. Despite the ability of some patients in MCS to resume oral feeding, a higher level of consciousness (i.e., EMCS) is probably necessary to allow a full return to ordinary oral feeding. Interestingly, in the study of Wang et al. [105], mouth opening was observed in only one UWS patient in their cohort and this patient recovers a MCS state of consciousness 6 months later. An effective oral phase should be considered as a sign of consciousness and, consequently, it should be taken into account in diagnosing DoC.

There also seems to be a difference between patients with UWS and MCS regarding pharyngeal components of swallowing. Patients with UWS and MCS differed in their spontaneous saliva management [41]. Indeed, patients with UWS had more pharyngo-laryngeal secretions and saliva aspiration and a larger proportion present extubation failure and still had a tracheostomy in place at the time of the evaluation [41, 102]. These results suggest that there is a link between the pharyngeal phase of swallowing and level of consciousness in this cohort. However, at this point, we are not able to identify whether the mechanism involved is a decrease in the frequency of spontaneous swallowing or a lack of efficacy of the pharyngeal phase as such, especially pharyngeal propulsion.

The cough reflex ("evoked cough" if we refer to Eccles's classification [118]) was another component that was more evident in MCS than with UWS [41]. This result support the fact that evoked cough is not solely a brainstem-mediated reflex response but is a sensorimotor behavior under cortical influence [119, 120]. Indeed, the impact of level of consciousness on the existence of the cough response may be linked to the scope of the underlying cortical damage.

Section 4: Evaluation and Treatment of Swallowing in Patients with DoC

Assessment of Swallowing

Determining the efficacy of swallowing in patients with DoC is difficult and challenging because they may not respond to commands (UWS, MCS–) and their responses may fluctuate.

Most such patients are fed by enteral nutrition because of severe dysphagia [41]. Understanding swallowing disorders in this population will help clinicians determine the nature and judge the efficacy of the therapy to be applied. Moreover, a better understanding of the pathophysiology of swallowing in patients with DoC will also contribute to our understanding of the links between consciousness and swallowing.

Classically, we distinguish between clinical bedside assessments and objective swallowing assessment (e.g., FEES and VFSS).

A series of screening protocols or bedside assessments have been developed in the last 20 years to explore swallowing [121]. However, most of them require the patient to participate actively (respond to commands) and therefore are not suitable for assessing swallowing in patients with DoC.

Three behavioral assessments developed for patients with DoC include a swallowing subscale or item: the Disorders of Consciousness Scale (DOCS) [122, 123], the Comprehensive Assessment Measure for the Minimally Responsive Individual (CAMMRI) [124] and the CRS-R [28].

One of the eight DOCS subscales is called “Taste & Swallowing” [122, 123]. It evaluates patient response to pre-swallowing stimulation (when we explain that we will apply the stimulation) and the ability to swallow within 15 to 20 s of a stimulation. The taste stimulation consists in touching the lips and gums with a cotton swab soaked in orange juice and observing the patient’s reactions (no response, generalized response or localized response). This item has the advantage of avoiding a functional swallowing test, which can expose the patient to a high risk of inhalation.

The CAMMRI includes a 7-item dysphagia rating scale ranging from “profound dysphasia” to “functional swallowing” [124]. It consists of a checklist that requires clinicians to evaluate oral motor impairment, pharyngeal phase of swallowing, cough reflex, secretion management, risk of aspiration and type of feeding. To be objective, this scale requires a FEES or VFSS to be performed. The CAMMRI also has an oral/facial sensitivity subtest that assesses reaction to firm and soft touch on the face and inside the mouth [124].

The CRS-R includes baseline observations of spontaneous behaviors including sticking out the tongue and opening and closing the mouth. On the motor function scale, in the “automatic motor response” item, if the patient does not show episodes of automatic motor behaviors, the examiner can propose to test mouth-opening ability when a spoon is presented. However, this item is proposed only if the examiner judges that the patient presents an inability to move their limbs and is not able to perform a wave sign. Moreover, the item tests the ability to inhibit the automatic motor behavior of opening the mouth when a spoon is presented because we ask the patient not to move at all.

Bicego et al. [125] developed an observation chart based on the Facial Oral Tract Therapy (FOTT) tool. The FOTT is a rehabilitation approach that can be used with patients with DoC as it does not require active participation [110]. This tool contains a series of items related to head and body posture, orofacial area (e.g., lip and jaw position, aperture of the jaw, appearance of the lips, tongue and cheeks), oral and perioral sensitivity, saliva swallowing, respiration, and cough and orofacial reflexes. They also proposed a bolus swallowing test. Although it is appropriate for patients with DoC, this tool is only available in French and has not been validated with a cohort of patients with DoC.

Similarly, we recently published a protocol study that aims to validate the SWallowing Assessment in Disorders of Consciousness (SWADOC). This bedside assessment has been developed to assess components related to swallowing in patients with DoC [126]. The SWADOC was inspired by Bicego et al. [125] assessment. It includes both qualitative and quantitative items. Items are grouped into 11 categories: (1) Arousal; (2) Resting position of the head, eyes, mandibles and lips; (3) External facial stimulations; (4) Initiation of mouth opening; (5) Mouth cavity observations; (6) Initiation of the saliva swallowing reflex; (7) Stimulation of the saliva swallowing reflex; (8) Lip prehension, tongue propulsion and reactions to 5 mL functional test; (9) Respiration; (10) Voice, speech, language; and (11) Tonicity and sensitivity profiles. A subsection of the SWADOC, the “SWADOC-scored”, includes only eight quantitative items (four items related to the oral phase and four to the pharyngeal phase). Items of the SWADOC-scored must be scored as one of the four severity levels indicated for each item (scores from 0 to 3). The SWADOC-scored allows one to calculate three performance scores: the oral phase subscore, the pharyngeal phase subscore and the total swallowing score (maximum 24). Concurrent validity is assessed with the Facial Oral Tract Therapy Swallowing Assessment of Saliva (FOTT-SAS) [127]. This scale has seven questions: if items 1 to 4 are answered “Yes” and items 5 to 7 are answered “No,” oral intake should be initiated (see Table 5).

Clinical bedside assessments are essential in day-to-day clinical work to gain an initial idea of a patient’s swallowing capacity, guide therapy and track progress. However, they remain subjective because hypotheses are made based on external signs of dysphagia (e.g., cough, voice changing). To objectively determine the efficacy of the pharyngeal phase of swallowing, an objective swallowing assessment is mandatory (FEES or VFSS). Such swallowing assessments, performed by experienced clinicians, constitute the gold standard tools to assess dysphagia in patients at high risk of inhalation [128, 129]. They allow the mechanisms at play during swallowing to be analyzed more precisely and possible silent aspiration to be detected. The high prevalence of silent aspiration in patients with DoC [41] makes the combination of a bedside clinical assessment with an objective swallowing assessment essential.

Table 3 Characteristics of studies exploring the relation between level of consciousness and swallowing-related abilities in patients with severe brain injury

Author, Date; Study year	Type of cohort study; Level of evidence[a]	Number of participant and etiology	Time since injury	Consciousness evaluation (single administration except when it is mentioned)	Level of consciousness (mean and/or range)	Swallowing components studied	Results
Winstein (1983) [106]; Jan 1980–Sept 1981	Retrospective chart review; 2b	55 TBI	"Non-acute"	RLA	Level III–V	Enteral or oral feeding (and type of feeding)	- Trend (no statistical analysis) between RLA score and type of feeding (enteral or oral feeding and type of oral feeding): on admission, 77% of the patients with enteral feeding had at best an RLA level IV and the majority were at level II or level III. For patients with oral feeding and dysphagia, 70% were at level V or higher and 30% were at level III. At discharge, patients remaining on enteral feeding were at the cognitively unresponsive level (level I), or at best the generalized response level (level II), and demonstrated severe oral-facial hypersensitivity or primitive responses
Mackay et al. (1999a) [7]; 1992–1995	Prospective; 2b	54 severe TBI with initial GCS score < 9	17.6 days post-injury (range 3–72 days)	RLA	In admission: 2.8 ± 0.7 Level II–IV	- VFSS: normal or abnormal swallowing[b] and presence or absence of aspiration - Length of ventilation - Time until initiation of oral feeding, achievement of exclusively oral feeding and time between the two	- Normal/abnormal swallowing: significantly different RLA scores in patients with normal swallowing than in patients with abnormal swallowing at the time of exclusively oral feeding but not at admission - Rate of aspiration: as the RLA score upon admittance decreased, the rate of aspiration (different bolus and consistencies) later identified by VFSS increased - Length of ventilation; no correlation with RLA score
Mackay et al. (1999b) [107]; 1992–1995	Prospective; 2b	Same as Mackay et al. (1999a) [7]	Same as Mackay et al. (1999a) [7]	RLA	In admission: Level II –IV	Same as Mackay et al. 1999a	- Normal/abnormal swallowing: patients with lower RLA levels had higher percentage of abnormal swallowing - Type of feeding: patients with lower RLA levels took more time to initiative and achieve exclusive oral feeding and interval between the two. RLA score is the most important independent predictor of the delay until exclusively oral feeding is achieved - Length of ventilation: approximately three times longer for patients with lower RLA scores
O'Neil-Pirozzi et al. (2003) [108]; Not mentioned	Prospective; 2b	50 severe TBI with tracheostomy: 12 DoC (RLA II or III) and 38 without DoC Initial GCS score < 9	Mean days post-injury: 78.6 (range 31–306 days) Median: 42.5 days	RLA	Level II–III	VFSS: presence or absence of aspiration and food and/or drink recommended	- Presence of aspiration: no statistically significant differences between groups

Table 3 (continued)

Author, Date; Study year	Type of cohort study; Level of evidence[a]	Number of participant and etiology	Time since injury	Consciousness evaluation (single administration except when it is mentioned)	Level of consciousness (mean and/or range)	Swallowing components studied	Results
Millwood et al. 2005 [104]; 12-month period	Not mentioned; 2b	45 ABI (UWS or MCS) patients	Mean of 8 months	SMART	UWS MCS	Presence or absence of abnormal reflexes and lip injury	- No association between scores for awareness, oral reflexes, and lip injury
Brady et al. (2006) [39]; 30 month timeframe	Retrospective; 3b	25 ABI Group 1: oral feeding initiated at RLA III Group 2: oral feeding not initiated until the patient reached RLA IV or was never initiated	Mean time from the injury until inpatient rehabilitation admission: 89 days	RLA	Level II – III	- Diet levels - FEES or VFSS (pharyngeal swallowing components: presence or absence of aspiration, laryngeal penetration, and pharyngeal residue)	- The two groups did not differ according to diet levels (three meals daily) at the time of discharge
Terré and Mearin (2007) [112]; Jan–Dec 2004	Prospective; 2b	48 TBI GCS score < 6	Neurorehabilitation unit: *Mean time from TBI to admission = 2 months (range 1–5 months) *Mean time from TBI to discharge = 6 months (range 4–11 months)	RLA	Group 1 ($n = 15$): level II–III Group 2 ($n = 19$): level IV–V Group 3 ($n = 14$): level VI–VIII	- Oral and pharyngeal components such as impaired tongue control, oral transit time, aspiration, penetration assess with clinical evaluation and VFSS at admission - Type of feeding at discharge	- Swallowing impairments (oral or pharyngeal deficits): difference in RLA scores when swallowing is assessed by videofluoroscopy but not between RLA scores and the clinical bedside examination - Impaired tongue control and oral transit time: correlated significantly with RLA scores - Penetration of the laryngeal vestibule: significant relationship with RLA scores - Type of feeding mode at discharge: substantially correlated with RLA scores at admission and at discharge
Hansen et al. (2008) [110]; Oct 2000–Dec 2005	Retrospective chart review; 2b	173 TBI Initial GCS score 9–13	Mean time until admission in the rehabilitation unit: 86 days	RLA	Level I–VIII	FOIS (the chance of reaching unrestricted dieting before discharge)	- Type of feeding: significant correlation with RLA score (patients admitted with RLA levels I to II had a 24% chance of engaging exclusively in ordinary oral feeding, whereas 77% of the patients admitted with RLA level III, 88% of the patients with RLA levels IV to V, and 100% of the patients with RLA levels VI to VIII achieved unrestricted feeding at the unit)
Hansen et al. (2008) [110]; Oct 2000–Dec 2005	Retrospective chart review; 2b	Same as Hansen et al. (2008) [110]	Same as Hansen et al. (2008) [110]	RLA	Level I–VIII	Risk of pneumonia	- Risk of pneumonia: association with RLA scores after adjustment for age and sex

Table 3 (continued)

Author, Date; Study year	Type of cohort study; Level of evidence[a]	Number of participant and etiology	Time since injury	Consciousness evaluation (single administration except when it is mentioned)	Level of consciousness (mean and/or range)	Swallowing components studied	Results
Brady et al. (2009) [100]; July 2002–June 2006	Retrospective; 2b	35 ABI	62.3 days ± 71.1 days post-insult	RLA	Group 1: Level II–III Group 2: > Level III	FEES or VFSS (diet levels, aspiration and laryngeal penetration rates)	- Difference in diet level between the two groups: therapeutic feeding was introduced in 76% of the patients in group 1 and 17% in group 2 and modified diet with 3 meals was introduced in 55,5% of patients in group 2 and not initiated in group 1 - Difference in the percentage of aspiration or laryngeal penetration between groups
Terré and Mearin (2009) [112]; Jan 2005–June 2007	Prospective; 3b	26 severe TBI GCS score < 6	12 months post-admission to the rehabilitation unit	RLA	Mean = 4 Level II–VII	VFSS (presence or absence of aspiration)	- Aspiration: significant relationship with RLA scores
Mandaville et al. (2014) [113]; June 2006–June 2011	Retrospective; 2b	219 severe TBI Initial GCS score < 9	Admission and discharge from a trauma unit of the hospital Mean time at admission = 10 days	RLA	Initial RLA: 4.5 ± 1.9	Presence or absence of feeding tube	- Percutaneous endoscopic gastrostomy tube at discharge: significant association (univariate and multivariate analysis adjusted for age) with RLA scores
Kjaersgaard et al. (2015) [103]; June 2009–Apr 2011	Retrospective; 2b	118 ABI	10–2845 days Median control group: 36 days Median intervention group: 35 days	RLA	Level III–VIII	Initiation of oral feeding Return to total oral feeding (both based on the FEES)	- Time of initiation and return to exclusive oral feeding: no significant association with RLA scores

Table 3 (continued)

Author, Date; Study year	Type of cohort study; Level of evidence[a]	Number of participant and etiology	Time since injury	Consciousness evaluation (single administration except when it is mentioned)	Level of consciousness (mean and/or range)	Swallowing components studied	Results
Bremare et al. (2016) [101]; Dec 2013– June 2014	Prospective; 3b	11 ABI = GCS score 3–13	69.3 ± 26.3 days post-insult	WHIM	5–57	- Type of feeding (oral or enteral) on admission - Clinical functional swallowing test (oral and pharyngeal swallowing components) - FEES (pharyngeal swallowing components) - FOIS (based on the clinical functional swallowing test and the FEES)	- Type of feeding: all patients were fed by enteral tube on admission. Of the 8 patients with severe TBI, 4(50%) resumed oral feeding 3 months after admission. We do not know if there was a link to the level of consciousness assessed with the WHIM - Presence of a tracheotomy: 3 out of 4 patients with UWS had a tracheostomy with inflated cuff. The fourth did not have a tracheostomy, but he could swallow on request and as such should not be considered as having UWS. Of the 6 patients with MCS, only 1 did not have a tracheostomy and the 5 others had a tracheostomy with inflated cuff - Aspiration with compote texture: of the 7 subjects (2 UWS based on the WHIM but 1 with command following, 3 MCS, 2 confusional state), 2 had aspirations (1 MCS, 1 UWS) and 1 (MCS) had pharyngeal residues - Aspiration with liquid texture: of the 4 subjects (2 UWS but 1 with command following, 1 MCS, 1 confusional state), 2 had aspirations (2 UWS) and none had pharyngeal residues
Godet et al. (2017) [102]; June 2013–Feb 2015	Prospective; 1b	140 ABI GCS < 13	Acute (Intensive Care Unit)	CRS-R FOUR	Group extubation success: CRS-R total score 10–19; FOUR total score 11–13 Group extubation failure: CRS-R total score 8–15; FOUR total score 10–13	Extubation failure	- Univariate analysis: visual functions, brainstem and arousal capabilities on the FOUR and CRS-R differentiated success from failure - Multivariate analysis: independently associated with CRS-R visual subscale
Mélotte et al. (2018) [40]; Dec 2006–May 2017	Retrospective; 2b	68 ABI	Median: 30 months	Repeated CRS-R and neuroimaging	UWS	Type of feeding	- Of 68 patients, only 2 were able to resume oral feeding (3%). Based on neuroimaging results, link between exclusive oral feeding and DoC diagnosis

Table 3 (continued)

Author, Date; Study year	Type of cohort study; Level of evidence[a]	Number of participant and etiology	Time since injury	Consciousness evaluation (single administration except when it is mentioned)	Level of consciousness (mean and/or range)	Swallowing components studied	Results
Wang et al. (2019) [105]; Not mentioned	Prospective; 1b	19 ABI	Median: 4 months (range 1–12)	Repeated CRS-R	UWS and MCS–	Initiation of mouth opening (1) on command; (2) placing a spoon in front of the patient's mouth without a command; (3) placing a spoon filled with water in front of the patient's mouth without a command; (4) one command ("there is a spoon; open your mouth") with a spoon in front of the patient's mouth; (5) one command ("there is a spoon with water; open your mouth") with a spoon filled with water in front of the patient's mouth	- Initiation of mouth opening: while none of the patients with DoC responded to the first 4 stimuli, 6 of them (5 MCS – and 1 UWS) initiated mouth opening with the fifth stimulus. Of these 6 patients (5 MCS – and 1 UWS), 5 had a good outcome 6 months later (i.e., MCS – had progressed to MCS + and UWS was now MCS –)
Mélotte et al. (2020) [41]; Jan 2010–August 2018	Retrospective; 2b	92 ABI	UWS: 30 ± 22 months MCS: 40 ± 34 months	Repeated CRS-R and FDG-PET	UWS and MCS	- Type of feeding - Presence or absence of tracheostomy - 8 components related to swallowing based on FEES (oral phase, effective oral phase, hypertonia of the jaw muscles, pharyngo-laryngeal secretions, saliva aspiration, cream aspiration, liquid aspiration, evoked cough)	- Exclusive enteral feeding: no significant association with DoC diagnosis - Tracheotomy and evoked cough: significantly associated with DoC diagnosis (multivariate analysis) - Oral phase: effective oral phase of swallowing (adequate lip prehension, tongue propulsion and no post-swallowing oral stasis) significantly correlated with the level of consciousness (multivariate analysis) but not hypertonia of the jaw muscles - Pharyngeal phase: DoC diagnosis significantly correlated with the presence of pharyngo-laryngeal secretions and saliva aspiration (univariate analysis) but not with liquid and cream aspiration

DoC disorders of consciousness, *TBI* traumatic brain injury, *ABI* acquired brain injury, *UWS* unresponsive wakefulness syndrome, *MCS* minimally conscious state, *GCS* Glasgow Coma Scale, *FDG-PET* fluorodeoxyglucose-positron emission tomography

Level of consciousness assessments: CRS-R = Coma Recovery Scale–Revised; FOUR = Full Outline of UnResponsiveness; RLA = Rancho Los Amigos Scale; SMART = Sensory Modality Assessment and Rehabilitation Technique; WHIM = Wessex Head Injury Matrix

Swallowing assessments: FEES = fiber-optic endoscopic evaluation of swallowing; VFSS = videofluoroscopic swallowing study; FOIS = Functional oral intake scale

[a]Level of evidence of the study based on the Oxford Centre for Evidence-based Medicine for "Differential diagnosis/symptom, prevalence study": 1b = Prospective cohort study with good follow-up; 2b = Retrospective cohort study, or poor follow-up; 3b = Nonconsecutive cohort study, or very limited population. https://www.cebm.net/2009/06/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/

[b]Swallowing mechanism was identified as abnormal if any oral or pharyngeal deficits were noted

Table 4 Summarized results of studies analyzing the link between level of consciousness and swallowing components

Consciousness evaluation scale	Author, Date	Respiration and protection of the airway	Type of feeding	Oral phase of swallowing	Pharyngeal phase of swallowing	Mixed components	Abnormal reflexes, lip injuries and hypertonia of the jaw muscles
RLA	Winstein (1983) [106]	–	Enteral or oral feeding and type of oral feeding: positive (low)	–	–	–	–
	Mackay et al. (1999a) [7]	Length of ventilation: negative (moderate)	–	–	Presence or absence of aspiration based on the VFSS: positive (low)	Normal vs. abnormal swallowing based on the VFSS: positive (moderate)	–
	Mackay et al. (1999b) [107]	Ventilation days: positive (moderate)	Time to initiative and achieve exclusive oral feeding and interval between the two: positive (moderate)	–	–	Normal/abnormal swallowing based on the VFSS: positive (low)	–
	O'Neil-Pirozzi et al. (2003) [108]	–	–	–	Percentage of aspiration based on the VFSS: negative (moderate)	–	–
	Brady et al. (2006) [39]	–	Diet levels at time of discharge: negative (moderate)	–	–	–	–
	Terré and Mearin (2007) [109]	–	Feeding mode at admission and at discharge: positive (moderate)	Impaired tongue control: positive (moderate) Oral transit time: positive (moderate)	Presence of penetration based on the VFSS: positive (moderate)	Oral or pharyngeal deficits: - Assessed by VFSS: positive (moderate) - Assessed by clinical evaluation: negative (moderate)	–
	Hansen et al. (2008) [110]	–	Chance of reaching unrestricted dieting before discharge: positive (moderate)	–	–	–	–
	Hansen et al. (2008) [110]	Risk of pneumonia: positive (moderate)	–	–	–	–	–
	Brady et al. 2009	–	Diet levels (assessed by FEES or VFSS): positive (low)	–	Aspiration and laryngeal penetration (assessed by FEES or VFSS): negative (low)	–	–
	Terré and Mearin (2009) [112]	–	–	–	Presence of aspiration based on the VFSS: positive (moderate)	–	–

Table 4 (continued)

Consciousness evaluation scale	Author, Date	Respiration and protection of the airway	Type of feeding	Oral phase of swallowing	Pharyngeal phase of swallowing	Mixed components	Abnormal reflexes, lip injuries and hypertonia of the jaw muscles
	Mandaville et al. (2014) [113]	–	Initial RLA score and presence of an endoscopic gastrostomy tube at discharge: positive (strong)	–	–	–	–
	Kjaersgaard et al. (2015) [103]	–	Time until initiation of oral intake and ability to return to total oral intake based on the results of a FEES: negative (moderate)	–	–	–	–
SMART	Millwood et al. (2005) [104]	–	–	–	–	–	Presence of oral reflexes and lip injury: negative (moderate)
WHIM	Bremare et al. (2016) [101]	Not clearly determined	Not clearly determined	–	Not clearly determined	–	–
FOUR	Godet et al. (2017) [102]	Extubation failure: positive (moderate)	–	–	–	–	–
CRS-R	Godet et al. (2017) [102]	Extubation failure: positive (strong)	–	–	–	–	–
	Mélotte et al. (2018) [40]	–	Type of feeding of patients with UWS: positive (low)	–	–	–	–
	Wang et al. (2019) [105]	–	–	Initiation of mouth opening: positive (low)	–	–	–
	Mélotte et al. (2020) [41]	Presence of a tracheostomy: positive (strong) Presence of an evoked cough: positive (strong)	Presence of exclusive enteral feeding: negative (strong)	Efficacy of the oral phase: positive (strong)	Pharyngo-laryngeal secretions: positive (moderate) Saliva aspiration: positive (moderate)	–	Hypertonia of the jaw muscles: negative (strong)

Results are presented based on the degree of evidence of a link between the component studied and the level of consciousness: positive or negative link and low (quantitative and/or qualitative analysis only); moderate (univariate analysis); or strong (multivariate analysis) evidence

UWS unresponsive wakefulness syndrome, *MCS* minimally conscious state, *CRS-R* Coma Recovery Scale—revised, *FOUR* Full Outline of Unresponsiveness, *RLA* Rancho Los Amigos scale, *SMART* Sensory Modality Assessment and Rehabilitation Technique, *WHIM* Wessex Head Injury Matrix, *FEES* fiber-optic endoscopic evaluation of swallowing, *VFSS* videofluoroscopic swallowing study, *FOIS* Functional Oral Intake Scale

Table 5 The facial oral tract therapy swallowing assessment of saliva (FOTT-SAS) (adapted from Mortensen et al. [127])

Items	Yes	No
1. Conscious and/or respond to verbal address?		
2. Able to sit upright with some degree of head control?		
3. Oral transport of saliva?		
4. Spontaneous or facilitated swallowing of saliva?		
5. Coughing following swallowing of saliva?		
6. Gurgling breath sound following swallowing of saliva?		
7. Difficulties breathing following swallowing of saliva?		
Based on the above questions, should oral intake be initiated?		

Oral intake should be initiated if items 1 to 4 = Yes and items 5 to 7 = No (no cross in the gray boxes)

Objective swallowing assessments can be challenging to do with patients with DoC. In Mackay et al. [7] study, one of the inclusion criteria to perform a VFSS was a level IV RLA score (corresponding approximately to EMCS). Moreover, a VFSS was performed only if patients were able to show automatic or volitional responses to presentation of food or a spoon (i.e., mouth opening). In contrast, Brady et al. [100] showed that FEES and VFSS are feasible in patients at levels II and III. In another study O'Neil-Pirozzi et al. [108] with acute tracheostomized patients with severe DoC following TBI, the authors argued that "these patients may be poor candidates when: (i) swallows are not observed spontaneously and cannot be elicited using digital stimulation to the laryngeal area; (ii) a profound bite reflex is present; and/or iii) the patient cannot tolerate an upright position for a minimum of 15 min" (p. 396). We also showed recently that an objective swallowing assessment can be successfully completed in patients with DoC but that a functional swallowing test (food or liquid testing) can be difficult if patients have severe trismus (lockjaw) or completely lack an oral phase of swallowing [41]. Together, this information suggests that four criteria are necessary when performing a functional swallowing test (liquid or solid food testing) with an objective swallowing assessment (FEES or VFSS) in patients with DoC: (1) semi-seated position for a minimum of 15 min; (2) mouth opening (automatic response to presentation of food or spoon or active opening without severe hypertonia of the jaw muscles); (3) at least minimal tongue propulsion; and (4) swallows are observed spontaneously or can be elicited using stimulation to the pharyngo-laryngeal area.

Treatment of Orofacial Area and Swallowing

Swallowing has not been studied much in patients with DoC, and swallowing treatment is even less studied. In 2010, the National Italian Consensus Conference drew up recommendations on rehabilitation programs for patients with severe ABI in the intensive hospital phase [130]. These recommendations include some indications concerning swallowing (see Table 6).

Other researchers have given some directions on how to manage swallowing in patients with DoC, such as using a nonfeeding program [106, 108]. A nonfeeding program consists in stroking, stretching, applying firm pressure or providing thermal and taste stimulations to desensitize inappropriate orofacial responses and facilitate more normal swallowing and intraoral responses. Recently, Jakobsen et al. [131] proposed a nonfeeding protocol of stimulation based on three specific preselected FOTT stimulation techniques (stroking of the gums and facilitation of tongue and hyoid movements) to non-tracheotomised patients with acute neurogenic dysphagia. They found a tendency to improvement of specific swallowing parameters (frequency of swallowing, elevation of larynx and speed of laryngeal elevation) in the intervention group [131]. However, for now, this is the only

Table 6 Indications concerning swallowing adapted from the National Italian Consensus Conference (De Tanti et al. [130])

1. Precise assessment of swallowing in all patients with ABI, even with LCF < 4
2. Bedside assessment of swallowing by the blue dye test by a doctor or an expert speech therapist
3. Detailed diagnosis by fiber-optic endoscopic evaluation of swallowing (FEES) and/or videofluorography, especially in cases suspected of silent aspiration. FEES is preferable for low-compliance patients
4. Swallowing training may be initiated in sufficiently wakeful patients (LCF 4 or more)
5. Dysphagia should be treated by a speech therapist experienced in this disorder and may include the use of appropriate measures of compensation
6. Use of a phonation valve for swallowing training in patients with tracheostomy, in the absence of contraindications
7. Inform family members about the timing of weaning to minimize the risk of inappropriate feeding

LCF Rancho Los Amigos—level of cognitive functioning

Table 7 Percentage of agreement of 40 speech and language therapists (SLT) with several items linked to the assessment and treatment of dysphagia in patients with prolonged disorders of consciousness (PDOC) (extracted from Roberts and Greenwood [133], pp. 7–8)

Assessment	Percentage of agreement
SLT assessment should include assessment of oral hypersensitivity/oral reflexes of patients in PDOC ($n=34$)	100
SLT assessment should include assessment of the ability of patients in PDOC to manage their oral secretions	100
SLT assessment should include assessment of the ability of patients in PDOC to tolerate cuff deflation and speaking valve (for tracheostomy patients) ($n=32$)	100
SLT assessment should include bedside assessment of swallowing of medically stable patients in a MCS/suspected MCS (if yet to be diagnosed)	97.2
SLT assessment should include instrumental assessment of swallowing of patients in PDOC ($n=35$)	80
SLTs working with patients in PDOC should refer to a speaking valve as a one-way valve ($n=29$)	79.3
SLT assessment should include bedside assessment of swallowing of medically stable patients in a UWS/suspected UWS (if yet to be diagnosed)	77.8
Patients in PDOC are frequently able to tolerate videofluoroscopy ($n=31$)	29.1
Patients in PDOC are frequently able to tolerate fiber-optic endoscopic evaluation of swallowing ($n=28$)	60.7
All patients in PDOC should have an instrumental swallowing assessment before commencing oral trials/therapeutic feeding ($n=35$)	40
SLTs should offer cough reflex testing for patients in PDOC	38.9
Treatment	
SLTs should provide programs to manage oral hypersensitivity in patients in PDOC ($n=35$)	100
SLTs should be involved in decision-making regarding the management of oral secretions of patients in PDOC ($n=40$)	100
SLTs should be involved in planning tracheostomy weaning of patients in PDOC ($n=32$)	100
SLTs should be involved in decision-making regarding the use of botulinum toxin for management of bite reflex	86.1
SLTs should provide FOTT to patients in PDOC ($n=35$)	54.3

PDOC prolonged disorders of consciousness, *UWS* unresponsive wakefulness syndrome, *MCS* minimally conscious state, *FOTT* Facial Oral Tract Therapy

published study examining the effect of these techniques on dysphagia in a population with neurological disease.

Brady et al. [39, 132] suggest that, if patients do not demonstrate aspiration in an objective swallowing assessment, therapeutic feedings can be used. Therapeutic feedings consist of giving small amounts of food to stimulate the oral and pharyngeal phases of swallowing and provide a positive experience for the patient.

A modified Delphi study requested speech language therapists' (SLT) opinions about best practices to assess and treat patients with DoC [133]. For the first time, an expert panel of 36 SLTs reached a consensus on 67 statements covering assessment, management and service delivery for patients in prolonged DoC. This study constitutes the starting point for developing SLT guidelines when working with patients with DoC. In Table 7, we report the statements related to the assessment or treatment of dysphagia and the percentage of agreement.

The Delphi study addressed the use of the FOTT [134] as part of the SLT intervention for patients with DoC but reported that only a small percentage of speech therapists are trained in its use. Moreover, only half of the participants agreed that SLTs should use the FOTT with patients in prolonged DoC. The authors also emphasized the lack of English language papers on that topic and the study design's limitations [135, 136]. Recently, a practice-oriented book on the FOTT was published that allows clinicians to learn more about this approach [137].

Discussion/Conclusion

As we described in the introduction, identifying signs of consciousness is essential regarding functional and survival prognosis [17, 18, 138], pain management [22] and end-of-life decisions [24]. The identification of behavioral signs of consciousness is historically based on the principle of differentiating reflexive from volitional behaviors, with the idea that unconscious patients show only purely reflexive behaviors while conscious patients show volitional behaviors [13]. However, some ambiguity still exists between conscious and reflexive behaviors [42]. In fact, there are no empirical characteristics that allow one to reliably distinguish reflexive behaviors from conscious behaviors [42].

Based on the characteristics of swallowing components in each phase of swallowing, we tried to distinguish voluntary from reflexive components of swallowing. Our classification is based on the characteristics of voluntary behavior and somatic and autonomic reflexes. We postulated that the triggering of the swallowing reflex constitutes the borderline between voluntary and reflexive behaviors. Components that occur before the initiation of the swallowing reflex (oral phase components) can be considered as voluntary while components that happen afterward (pharyngeal and esophageal components) can be considered reflexive. The opening of the UES constitutes the border between somatic reflexes (pharyngeal phase) and autonomic reflexes (esophageal phase).

In light of this information and based on the results of experimental studies, we will discuss the conscious or unconscious nature of each phase of swallowing.

Although they contain automatic processes, oral phase components can be interrupted, influenced and suppressed, placing them in the category of "voluntary behaviors." Based on our two retrospective studies in patients with DoC [40, 41], the efficacy of the oral phase seems to be the most robust sign of consciousness. Indeed, until now, no typical patients with UWS are described in the literature as having a complex oral phase of swallowing enabling the preparation and mastication of solid food. Therefore, oral phase components can be considered conscious components.

The triggering of the swallowing reflex can be initiated voluntarily but usually occurs below conscious control. Non-pathological consciousness studies have taught us that sleep and anesthesia tend to decrease the frequency of spontaneous saliva swallowing. Until now, there have been no data about the frequency of saliva swallowing in patients with DoC. However, we highlighted the link between spontaneous saliva swallowing and level of consciousness by highlighting the higher proportion of extubation failure, tracheostomies, pharyngo-laryngeal secretions and saliva aspiration in patients with UWS than in MCS [41, 102]. To identify which mechanism (the frequency of triggering of the swallowing reflex or the efficacy of the pharyngeal phase) is more influenced by consciousness, it would be interesting to explore the frequency of spontaneous swallowing in patients with different levels of consciousness. Based on existing data, we can postulate that the frequency of the swallowing reflex may be influenced by consciousness.

Previously, there were no data about the esophageal phase of swallowing in patients with DoC. Based on our theoretical assumptions, we postulate that the esophageal components of swallowing in the upper third of the esophagus can be influenced by the level of consciousness (but this still needs to be demonstrated) while the components of the lower two-thirds part of the esophagus are unconscious processes.

According to the literature and the main findings of our studies, the presence of oral phase components (mainly mouth opening, lip prehension and lingual propulsion) and the ability to receive exclusive oral feeding can be considered as signs of consciousness. Indeed, these components seem to be present only in patients with (E)MCS [41], with UWS patients that will recover a MCS state of consciousness [105] or in patients with MCS-like patterns of brain activity on neuroimaging tools [40, 41]. Several other components related to swallowing (see Table 8) can be considered to be linked to the level of consciousness (cortically mediated state) without constituting signs of consciousness as such, based on current data. Further prospective studies will help

Table 8 Hypotheses concerning which components of swallowing can be considered to be linked to level of consciousness according to the literature and the main findings of our studies

Components related to swallowing	Degree of evidence suggesting a link with level of consciousness → MCS > UWS but also present in some patients with UWS = cortically mediated behaviors
Oral feeding	–
Exclusive oral feeding	Moderate
Exclusive oral feeding with solid food	Strong
Components of the oral phase	–
Initiation of mouth opening	Moderate
Some lip prehension or tongue propulsion	Moderate
Efficient oral phase (lip prehension AND tongue propulsion without oral stasis post-swallowing)	Strong
Hypertonia of the jaw muscles or lip injury	Absent
Components of the pharyngeal phase	–
Frequency of saliva swallowing	Evidence not clearly determined hitherto
Ability to manage saliva (tracheostomy, pharyngo-laryngeal secretions or saliva aspiration)	Moderate
Pharyngeal propulsion	Evidence not clearly determined hitherto
Components of the esophageal phase	Evidence not clearly determined hitherto
Evoked cough reflex	Moderate

refine our understanding of these associations and determine which swallowing behaviors suggest consciousness in patients with DoC.

Finally, we reviewed current knowledge of the assessment and treatment of dysphagia in patients with DoC. In day-to-day practice, clinicians need to appraise and measure swallowing-related capacities in patients with DoC. However, the majority of existing tools are not adapted to these patients. Indeed, they require active participation by the patient or involve a functional test with a significant amount of liquid or solid food, exposing the patient to a high risk of aspiration. To address this problem, we developed a new tool—the SWADOC—and proposed a validation study.

Moreover, an objective swallowing examination performed by an otorhinolaryngologist is feasible and relevant for patients with DoC regardless of their level of consciousness and whether it is done to discuss the utility of maintaining a tracheostomy, document the utility of botulinum toxin to improve saliva management, or assess the feasibility of therapeutic feeding [39, 41, 101, 108].

Even though evidence regarding the benefits of stimulation is still scanty, there is growing evidence that patients with DOC need intensive rehabilitative interventions [139, 140]. These kinds of care can benefit patients who make functional progress but also those who do not, by reducing later acute care hospital readmissions and enhancing comfort [139].

The research field on the links between swallowing and consciousness deserves our attention, and there is an urgent need for clinical guidelines focusing on assessment and treatment of dysphagia in patients with DoC.

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Author Contributions EM reviewed the literature and drafted the article with the help of AM and OG. All authors reviewed it critically for important intellectual content and gave final approval of the revised manuscript.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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