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Coma scales

A historical review

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ABSTRACT

Objective: To describe the most important coma scales developed in the last fifty years. **Method:** A review of the literature between 1969 and 2009 in the Medline and Scielo databases was carried out using the following keywords: coma scales, coma, disorders of consciousness, coma score and levels of coma. **Results:** Five main scales were found in chronological order: the Jouvet coma scale, the Moscow coma scale, the Glasgow coma scale (GCS), the Bozza-Marrubini scale and the FOUR score (Full Outline of UnResponsiveness), as well as other scales that have had less impact and are rarely used outside their country of origin. **Discussion:** Of the five main scales, the GCS is by far the most widely used. It is easy to apply and very suitable for cases of traumatic brain injury (TBI). However, it has shortcomings, such as the fact that the speech component in intubated patients cannot be tested. While the Jouvet scale is quite sensitive, particularly for levels of consciousness closer to normal levels, it is difficult to use. The Moscow scale has good predictive value but is little used by the medical community. The FOUR score is easy to apply and provides more neurological details than the Glasgow scale.

Key words: coma, scales, consciousness, review.

Escalas de coma: uma revisão histórica

RESUMO

Objetivo: Apresentar as escalas de coma de maior relevância desenvolvidas nos últimos cinqüenta anos. **Método:** Foi realizado levantamento bibliográfico nos bancos de dados Medline e Scielo compreendendo o período de 1969 a 2009 de acordo com as palavras-chave: coma scales, coma, disorders of consciousness, coma score, levels of coma. **Resultados:** Foram encontradas cinco escalas principais, em ordem cronológica: Escala de coma de Jouvet, Escala de coma de Moscou, Escala de coma de Glasgow (GCS), Escala de Bozza-Marrubini e Escala FOUR (Full Outline UnResponsiveness), além de outras com menor repercussão e raramente usadas fora do seu país de origem. **Discussão:** Das cinco escalas principais, a GCS é, de longe, a mais usada. É de fácil aplicabilidade e bastante adequada para situações de trauma crânio encefálico (TCE), porém, apresenta falhas, como a impossibilidade de se testar o componente verbal em pacientes intubados, entre outras. A escala de Jouvet é bastante sensível, especialmente para níveis de consciência mais próximos do normal, no entanto, é de difícil execução. A escala de Moscou apresenta um bom valor preditivo, porém, é pouco usada pela comunidade médica. A escala FOUR é de fácil aplicação e fornece mais detalhes neurológicos se comparada à GCS.

Palavras-chave: coma, escalas, consciência, revisão.

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The state of consciousness is characterized by the ability to get in contact with reality, to recognize objects that are part of it and to interact with it. Consciousness has two main components: wakefulness and content. The first relates to the degree of consciousness, i.e., it represents a quantitative aspect. The second, on the other hand, is a qualitative aspect and is made up of functions mediated by the cortex; these include cognitive abilities such as attention, sensory perception, explicit memory, language, the execution of tasks, temporal and spatial orientation and reality judgment. There can be wakefulness without the content of consciousness, as occurs in the vegetative state. However, the content of consciousness can only exist in the wakeful state[1,2].

Although the neurological and anatomical aspects of consciousness have been exhaustively studied, many aspects remain unexplained. Wakefulness is related to the reticular activating system, a structure that originates in the tegmentum of the pons and mesencephalon and has projections into the diencephalon and cortical areas. The content of consciousness, on the other hand, depends on various cortical structures and their subcortical connections[1,3].

The spectrum of alterations in the level of consciousness varies progressively from obtundation, through delirium, torpor and stupor to coma. The last of these is the complete absence of wakefulness and content of conscience, which manifests itself as a lack of response to any kind of external stimuli[1]. A comatose state usually occurs in two circumstances: diffuse or extensive involvement of both hemispheres of the brain and situations in which there is a lesion in the brainstem[1,2]. Unilateral focal lesions very rarely lead to coma[1,4]. Coma can be caused by structural lesions (lesions of the central nervous system, such as ischemic and hemorrhagic lesions) or nonstructural ones (such as exogenous intoxication and metabolic disorders)[1,3]. It is potentially fatal and must be investigated quickly and systematically using a standardized neurological examination[3]. Certain clinical parameters can be used to correlate the anatomical and physiological aspects of coma with its etiology, such as state of consciousness, respiratory rhythmicity, pupillary size, eye movements, motor response, cranial nerves responses, evidence of trauma in neck or head, and optic fundi abnormalities[3-8]. Coma scales arose because of the need to standardize the language used and so make written and spoken communication of information related to coma between different health professionals easier. A further aim of coma scales is to provide a consistent system for following the evolution of the patient's level of consciousness. Lastly, they can also provide prognostic data, allowing treatment to be optimized and costs rationalized[6-8].

The aim of this study is to carry out a historical analysis of the most important and widely adopted coma scales developed in the last fifty years that have been of greatest importance and had the greatest impact.

METHOD

The literature in the Medline and Scielo databases and in journals between 1969 and 2009 was reviewed using the keywords coma scales, coma, disorders of consciousness, coma score and levels of coma, as well as specific terms for each scale. Studies that described or validated the scales were chosen.

RESULTS

We describe below the most important coma scales in the order in which they were published.

Jouvet scale

The Jouvet coma scale[9], which was published in 1969, evaluates two parameters: perceptivity and reactivity. The parameter reactivity is divided into three categories: specific, non-specific and autonomic. Perceptivity includes a set of acquired responses, which depend on the integrity of the cortical function as well as that of the thalamocortical system. It is assessed by means of the following tests: [1] asking the patient to obey a written order; [2] asking the patient where they are and what the day, month and year are; [3] asking the patient to obey a verbal command. The individual can be classified in one of five categories: P1: No loss of consciousness, neurologically normal as far as level of consciousness is concerned. P2: This represents obtundation. Patients in this category are disoriented in time or space or are unable to obey a written command but can obey a verbal one. P3: This represents torpor. This category includes individuals with poor understanding of language. A verbal command needs to be repeated many times for it to be obeyed, and even then it is carried out slowly. Blinking reflex is normal. P4: Patients who only have the blinking reflex. P5: A complete absence of perception, indicating an organic or functional impairment of the cortical neurons[9].

Reactivity is innate, or inborn, and is largely dependent on connections at the subcortical level. Non-specific reactivity is tested based on eye orientation and opening responses. If the patient has their eyes open, the examiner should say the patient's name out loud and observe whether the orienting response is present. If it is, the patient will first move their eyes in the direction of the sound and then their head. If the patient has their eyes closed, the examiner should call the patient's name out loud and observe whether there is an eye opening response (also known as the waking reaction). Based on this, the individual can be classified in one of three groups: R1: Positive orientation reaction with eyes open

and positive waking reaction if eyes are closed. R2: Eye opening but loss of orientation reaction with eyes open. R3: Loss of eye opening response[9].

Patient response to pain can be divided into four categories: D1: Normal response. Characteristic facial mimic, possibly with crying and limb withdrawal. D2: Loss of facial and vocal response to pain. Waking reaction when stimulated during sleep still present. Limb withdrawal. D3: Only limb withdrawal. D4: Absence of any response to pain[9].

Autonomic reactivity provides an assessment of the autonomous nervous system response to painful stimuli. Response to pain causes a period of apnea followed by tachypnea. Heart rate may increase or decrease. There are frequent vasomotor changes, causing rubor and sweating. Mydriasis is also common. This indicator can be used to include patients in one of two groups: V1: Autonomic responses to painful stimuli are present. V2: Absence of autonomic response to pain[9].

Lastly, the classic (tendon, cutaneous and swallowing) reflexes are tested. The final score on this scale is obtained by adding the numbers after the letters for each item assessed. The overall score varies between 4 (P1R1D1V1) and 14 (P5R3D4V2)[9].

Based on the above classifications, his own clinical observations and other cases reported in the literature, Jouvet identified four states related to deep coma. The first of these is reactive apathic hypoperceptive syndrome, which covers individuals in whom perception is altered but not eliminated (P3-P4). Autonomic reactivity and autonomic functions are also normal. The response to a painful stimulus, however, is partially altered. The second state corresponds to hyperpathic-hypertonic aperceptivity syndrome, which is equivalent to decortication. There is no perception at all (P5), and reactivity is normal. The rigidity and flexor posturing found in decortication are present. The third state, areactive apathic normotonic aperceptivity syndrome, is characterized by deep coma, in which survival is limited to a few weeks. Perceptiveness is absent (P5) and non-specific reactivity is altered (R2-R3), as is response to pain (D2-D3). However, autonomic responses are normal, and in most cases there is no hypertonicity. Finally, the last state, areactive apathic and atonic aperceptivity syndrome, corresponds to brain death (Coma Dépassé) and only exists because of resuscitation techniques[9] (Tables 1 and 2).

Moscow scale

The Moscow coma scale was developed by the Institute for Research into Neurosurgery at the USSR Academy of Medical Sciences[10]. It consists of a quantitative

Table 1. Levels of perceptivity in Jouvet's coma scale[9].

Perceptivity	Execution of written orders	Orientation in time and space	Execution of spoken order	Blinking to threat
P1	+	+	+	+
P2	–	+	+	+
P3	–	–	+/–	+
P4	–	–	–	+
P5	–	–	–	–

Table 2. Levels of reactivity in Jouvet's coma scale[9].

Unspecific reactivity	Orientation reaction	Eye opening reaction	–	–
R1	+	+		
R2	–	+		
R3	–	–		
Reactivity to pain	Facial mimic	Eye opening	Limb withdrawal	–
D1	+	+	+	
D2	–	+	+	
D3	–	–	+	
D4	–	–	–	
Autonomic reactivity	Respiratory variation	Vasomotor changes	Cardiac rhythm changes	Pupil size changes
V1	+	+	+	+
V2	–	–	–	–

scale for the findings of the neurological examination and a scale for classifying disorders of consciousness, thus allowing the findings of the examination to be correlated with certain clinical conditions.

It was shown in a study that there is a critical value corresponding to 15 points as all the patients in the study whose scores after assessment were less than this value died[10] (Tables 3 and 4).

Glasgow coma scale (GCS)

The Glasgow coma scale (GCS) is extensively used throughout the world by physicians and other health professionals. Since its introduction in 1974[11,12], it has proved to be particularly suitable for characterizing the severity of changes in consciousness, especially in patients suffering from traumatic brain injury. At the time the scale was published, the authors, Jennett and Teasdale, believed that the lack of guidelines for describing patients with altered consciousness caused difficulties with communication between different centers and also made it difficult to compare groups of patients treated using different methods[14]. Unlike Plum and Posner[1], who concentrated on explaining precisely and accurately the diagnosis of stupor and coma, Jennett and Teasdale limited themselves to developing a practical method for obtaining an overall idea of the level of consciousness[5].

The total score on the Glasgow scale is obtained by assessing the following three parameters: eye opening, best verbal response and best motor response. The score varies between 3 and 15 points, and values of 8 or less correspond to serious conditions requiring intubation[11,12] (Table 5).

Bozza-Marrubini scale

In 1983, Bozza-Marrubini reviewed the existing systems for classifying coma[13]. First, he separated them into systems using scales and those using scores. In systems in the former category (those using scales), the clinical parameters are considered to be dependent and continuous; for example, a verbal response cannot be viewed as separate from a motor response, as this would theoretically result in different levels of consciousness. In systems in the latter category (those using scores), this premise is no longer valid, as different aspects of the patient are analyzed, a score is assigned for each of these and the scores are then added to give a number corresponding to the patient's clinical condition. According to Bozza-Marrubini[13], the correct approach would be to use a system of scales that meets the three following basic requirements: it favors a common language that overcomes the barriers of time, space and specialty; it allows a series of patients to be assessed therapeutically; and it provides a means of predicting the clinical outcome and thus determining how to allocate resources to those patients

Table 3. Moscow coma scale: quantitative scale of alterations observed in neurological examination[10].

Findings in neurological examination	Score
Eye opening in response to sound or pain	10
Oculocephalic reflex	10
Obeys instructions	8
Answers to questions	5
Orientation in time and space	5
Bilateral mydriasis absent	5
Flaccidity absent	5
Respiration not disturbed	4
Corneal reflex present	4
Patelar reflex present	4
Pupil reaction to light	4
Cough reflex	3
Skew deviation absent	3
Spontaneous movements	3
Movement to pain stimuli	3
Total	75

Table 4. Moscow coma scale: classifications of consciousness levels[10].

	Neurologics findings						
Consciousness level	VOR	Open eyes to pain	Follows commands	Answers questions	Oriented	Non reactive bilateral mydriasis	Atonia
Total conscious	+	+	+	+	+	–	–
Moderate torpor	+	+	+	+	–	–	–
Deep torpor	+	+	+	–	–	–	–
Vegetative state	+	+	–	–	–	–	–
Moderate coma	+	–	–	–	–	–	–
Deep coma	–	–	–	–	–	–	+
Irreversible coma	–	–	–	–	–	+	+

VOR: vestibulo-ocular reflex.

Table 5. Glasgow coma scale[11].

Clinical parameter			Points
Eyes	Open	Spontaneously	4
		To verbal command	3
		To pain	2
	No response	–	1
Best motor response	To verbal command	Obeys	6
	To painful stimulus	Localizes pain	5
		Flexion withdrawal	4
		Flexion abnormal (decorticate rigidity)	3
		Extension (decerebrate rigidity)	2
		No response	1
Best verbal response	Oriented		5
	Confused		4
	Inappropriate speech		3
	Incomprehensible speech		2
	No response		1
Total			(3-15 points)

Table 6. Bozza-Marrubini's scale[13].

Level/reactivity reflexes	Reactivity to voice	Reactivity to pain	Brain stem reflexes (VOR/LR)
1	Answers	Localizes	Present
2	Obeys	Localizes	Present
3	No response	Localizes	Present
4	No response	Flexion	Present
5	No response	Extension	Present
6	No response	Any type or no response	Both absent or VOR disconjugate only
7	No response	None	Both absent

VOR: vestibulo-ocular reflex; LR: pupillary reflex.

who have the greatest chance of benefitting from them[23]. Based on this, he proposed a system of scales made up of 7 levels for classifying organic brain damage, which are described as: [1] The highest level, in which the patient is able to speak and obey commands, obviously not intubated; [2] Patient obeys commands. Eye opening is therefore only one criterion and can be substituted by a similar one if, for example, the patient has an eyelid edema that makes eye opening impossible; [3] Patient is able to locate pain; [4] From this level on, the patient is no longer able to locate a painful stimulus but responds to it with abnormal flexion; [5] Limb extends abnormally in response to pain; [6] From this level on, there is no brainstem reflex or only disconjugate vestibulo-ocular reflex, which does not happen in the levels above. In addition, there is no pattern of response to painful stimuli or no response. Stage preceding brain death; [7] Complete absence of response to pain, and no brainstem reflex. Stage corresponding to brain death[13] (Table 6).

Full Outline UnResponsiveness - FOUR Score

In 2005, Wijdicks et al. published a new coma scale, the FOUR score[14]. It involves assessment of the following four components, each on a scale with a maximum of four: eye response, motor response, brainstem reflexes and respiration. This scale is able to detect conditions such locked-in syndrome and the vegetative state, which are not detected by the GCS.

When assessing eye response, the best of three attempts is used. E4 indicates at least three voluntary movements in response to the examiner's commands (for example, asking the patient to look up, look down and blink twice). If the patient's eyes are closed, the examiner should open them and observe whether they track

Table 7. Full Outline of UnResponsiveness - FOUR Score[14].

	Findings	Score
Eye response	Eyelids open or opened, tracking, or blinking to command	4
	Eyelids open but not tracking	3
	Eyelids closed but open to loud voice	2
	Eyelids closed but open to pain	1
	Eyelids remain closed with pain	0
Motor response	Makes sign (thumbs-up, fist, or peace sign)	4
	Localizing to pain	3
	Flexion response to pain	2
	Extension response to pain	1
	No response to pain or generalized myoclonus status	0
Brainstem reflexes	Pupil and corneal reflexes present	4
	One pupil wide and fixed	3
	Pupil or corneal reflexes absent	2
	Pupil and corneal reflexes absent	1
	Absent pupil, corneal, and cough reflex	0
Respiration	Not intubated, regular breathing pattern	4
	Not intubated, cheyne-stokes breathing pattern	3
	Not intubated, irregular breathing	2
	Breathes above ventilator rate	1
	Breathes at ventilator rate or apnea	0

a moving object or the examiner's index finger. If one of the eyes is affected by eyelid edema or trauma, the response of the healthy eye alone may be used. If there are no horizontal movements, check for vertical movements. E3 indicates the absence of any tracking movement with eyes open. E2 indicates eye opening in response to a loud sound, and E1 corresponds to eye opening in response to a painful stimulus. E0 indicates no eye opening even after a painful stimulus[14].

Motor response is assessed preferably at the upper extremities. A test is performed to determine if the patient is able first to abduct their thumb and simultaneously flex their four fingers (thumbs up), flex their fingers and thumb together (fist) and then extend just their index and middle fingers (V sign). If they are able to do this, the patient is classified as M4. If the patient's only response is localization to pain, they are classified as M3. Flexor response to pain is classified as M2, extensor response as M1 and a complete lack of response or generalized myoclonus status is classified as M0[14].

The brainstem reflexes tested are the pupillary and corneal reflexes. The corneal reflex is tested by applying two or three drops of sterile saline solution from a distance of 4 to 6 inches (to minimize corneal trauma as a result of repeated examinations). Cotton swabs can also be used. When both (pupillary and corneal) reflexes are absent, the cough reflex is also tested. B4 indicates the presence of pupillary and corneal reflexes. B3 indicates that one of the pupils is wide and fixed. B2 indicates the absence of one of the reflexes. B1 corresponds to the absence of both reflexes. B0 indicates that all the reflexes are absent, including the cough reflex[14].

For respiration, non-intubated patients with a normal breathing pattern are classified as R4, non-intubated patients with a Cheyne-Stokes breathing pattern as R3 and non-intubated patients with an irregular breathing pattern as R2. Patients on mechanical ventilation are classified in R1 if they are breathing above the ventilator rate (indicating that the respiratory center is still working) and in R0 if they are breathing at the ventilator rate or have apnea[14].

If the patient scores zero in all the categories, the examiner should consider the possibility of a diagnosis of brain death[14] (Table 7).

DISCUSSION

Coma scales have been developed throughout the world to standardize both the communication between

members of health teams and the assessment of the clinical evolution of severely affected patients. By far the most commonly used scale is the Glasgow coma scale. Various other scales have been developed, some of which are seldom used outside their country of origin[14]. Examples of these are the Innsbruck coma scale[6] and the Japanese scale[15]. They all generally involve assessing the patient and awarding a score that gives an overall idea of their level of consciousness.

The main advantage of the Jouvet scale is that it allows anatomo-clinical correlations to be established. However, the scale is complex, difficult to use and time-consuming and thus unsuitable for emergencies such as TBI. Compared with the Glasgow scale, it is more sensitive for levels of consciousness that are close to normal.

The Moscow scale is rarely used nowadays. Only one paper about this scale was found in our review of the literature[10]. In the study described in the paper, 58 traumatic brain injury (TBI) victims with Glasgow scores of three were also assessed with the Moscow scale. Of these 58 patients, only 69% died, whereas all those who had scores of less than 15 on the Moscow scale died. This finding led to the definition of a critical value of 15 points, below which the prognosis is brain death. The study concluded that the Moscow scale has good predictive value[10].

The Glasgow scale was developed using simple parameters for the specific purpose of allowing less experienced doctors and other health professionals to produce an accurate report of a patient's state of consciousness. Nevertheless, it has become the target of various criticisms in recent decades, and a number of studies have already described its strengths and weaknesses[5]. Eye opening, for example, is considered to indicate wakefulness, but it should be remembered that eye opening does not mean that the content of consciousness is intact (as in a persistent vegetative state). The fact is that the Glasgow scale does not provide either a sufficient number of or suitable tools to cover the whole spectrum of changes in consciousness. Rather, it is limited to diagnosis of the state of coma and does not allow more precise distinctions between the other states of consciousness to be made.[5] Because of this its usefulness for inferring a prognosis is limited, especially in patients with intermediate scores. As it lacks precision, the Glasgow scale is not suitable for monitoring changes of certain magnitudes in the state of consciousness[5,14,16,17].

In addition, Jennett and Teasdale specified that the score should be calculated based on examination of the patient six hours after the traumatic brain injury[18]. Patients with TBI are stabilized much sooner, and neuromuscular blocking drugs are often used to make it easier to transport and intubate agitated patients. All these circumstances interfere in the validity of the initial score obtained[19-21].

Another problem when applying the Glasgow scale is that the verbal component cannot be tested in intubated patients. Some physicians use the lowest score possible[1], while others infer the verbal response based on other findings of the neurological examination. Furthermore, abnormal brainstem reflexes, altered breathing patterns or the need for mechanical ventilation can indicate the severity of the coma, but the Glasgow scale does not cover these parameters[14].

The Bozza-Marrubini scale was an attempt to combine the standardized language of the Glasgow scale with exact descriptions of each clinical level. It is worth highlighting the efforts made by Bozza-Marrubini to find alternative ways to assess the same item, as in the case of the response to a verbal command, where the commands can include the alternatives "close your eyes" and "stick your tongue out", as seen in level 2 of the scale.[13]

Lastly, the FOUR score is easy to use and provides more neurological details than the Glasgow score, partly because it includes brainstem reflexes. Another advantage is that it allows different stages of herniation and other disorders such as locked-in syndrome and the vegetative state to be identified. It does not include verbal response and therefore has a higher predictive value for patients in intensive care[14]. A recent study showed that the scale can be used successfully by different professionals from outside the field of neurosciences[22].

Although scales are of tremendous importance in assessing disorders of consciousness, it should be stressed that instruments intended to assess something as complex as consciousness naturally have certain limitations. For some authors the items on a scale and the values assigned to them are still not able to consistently specify and quantify in all possible clinical coma situations the extent to which the various cerebral cortical functions related to the level of consciousness have been affected[1,5,7,14].

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