Evolution of apnoea test in brain death diagnostics

Joanna Sołek-Pastuszka¹, Wojciech Saucha², Waldemar Iwańczuk³, Romuald Bohatyrewicz¹

¹Department of Anesthesiology and Intensive Care Medicine, Pomeranian Medical University Szczecin, Poland
²Clinical Department of Cardiac Anesthesia and Intensive Care of Silesian Center of Heart Diseases, Medical University of Silesia, Zabrze, Poland
³Department of Anesthesiology and Intensive Care Medicine, Ludwik Perzyna Regional Polyclinical Hospital, Kalisz, Poland

Abstract

The concept of brain death (BD) was initially described in 1959 and subsequently became widely accepted in the majority of countries. Nevertheless, the diagnostic guidelines for BD markedly differ, especially regarding the apnoea test (AT), a crucial element of clinical BD confirmation. The current basic guidelines recommend preoxygenation rather than disconnection from the ventilator and insertion of an oxygen insufflation catheter into the endotracheal tube. Although a properly prepared and conducted AT is relatively safe, it has to be aborted in cases of serious disturbances, such as severe cardiac arrhythmia, cardiac arrest, hypotension, hypercarbia, desaturation and tension pneumothorax. These complications may be more frequent in patients with previously existing risk factors, such as poor oxygenation, severe acidosis, hypotension and cardiac rhythm disturbances. Airway injuries can occur if the insufflation catheter is placed too deep or catheter-related obstruction of the intubation tube occurs. It is widely accepted that AT should be performed as the very last BD diagnostic procedure due to its possible lethal consequences. Reports concerning the possible pitfalls of AT and confounding situations have inspired attempts to determine the most effective and safe method of AT. The use of CPAP with oxygen supplementation is becoming highly popular. CPAP can be generated in three manners: directly by the ventilator; through the use of a CPAP valve with a reservoir; and through the use of a highly traditional T-piece system with a reservoir bag connected to distal tubing immersed in water.

Key words: brain death, diagnosis, apnoea test

The first descriptions of patients with brain death (BD) syndromes were presented in France in 1959, and between the late 1960s and early 1970s, BD was proposed as a medical state. Despite the wide acceptance of the existence of this medical state, there is no unified international agreement for the standard of care during BD diagnosis. Guidelines regarding the confirmation of BD have been developed in up to 80 countries worldwide, and there are differences between the guidelines used in different countries regarding the criteria for beginning diagnostic procedures, the types of clinical and imaging evaluations performed and how to interpret the results of the diagnostic procedures [1].

In 2014, Citerio et al. [2] conducted a surveillance study in 33 European countries using an electronic tool to examine the standards of BD diagnosis. The information obtained from 28 countries showed that in the majority of those countries, laws and guidelines regarding BD diagnosis were developed by scientific societies. In Great Britain and Ireland, only guidelines developed by scientific societies exist, and Belgium, Norway and Italy have laws but no supporting guidelines from scientific societies.

The apnoea test (AT) is one of the most important evaluations conducted during BD diagnosis. The “Harvard criteria” from 1968 define apnoea as a lack of breathing movements for 3 minutes, providing that the baseline partial pressure of CO₂ (before starting the test) is in the normal range [3]. In contrast, the Minnesota criteria from 1971 define apnoea as a lack of breathing movements for 4 minutes [4].
In 1976, British criteria were published, and they recommended a procedure for apnoea evaluation that is very similar to the procedure currently used in Poland, i.e., before performing the main test, the patient is ventilated with 100% oxygen for 10 minutes; then, the patient is disconnected from the ventilator and undergoes oxygen insufflations at a speed of 6-10 l min⁻¹ through the catheter into the endotracheal tube. Implementation of this procedure highlighted for the first time the problems associated with the performance of AT in patients with lung diseases. As an alternative, ventilating the patient for 5 minutes with a mixture of 5% CO₂ and 95% O₂ was proposed in order to shorten the time that the patient is disconnected from the ventilator [5].

In 1981, the American Presidential Commission criteria were established and precisely described the conditions and mode of AT that should be used. These criteria included preoxygenation through the catheter into the endotracheal tube for at least 10 minutes, a test duration of 8–10 minutes, and a threshold PaCO₂ level of > 60 mm Hg [6].

In 1995, the American Neurology Academy criteria recommended that AT should not be performed in patients with chronic CO₂ retention and hypoxic respiratory drive or in pregnant women. The prerequisite to performing AT were also presented in those criteria: systolic blood pressure (SBP) > 90 mm Hg, normocarbia, normothermia, and PaO₂ after preoxygenation of > 200 mm Hg. Additionally, these criteria listed the adverse changes in the patient’s general condition that indicate the need to disrupt the test: cardiac arrhythmia, hypotension with SBP ≤ 90 mm Hg, and significant desaturation (SpO₂ < 85%) [7]. The need to perform AT has been questioned (in paediatric literature), and some authors have proposed to limit the test to only one probe [8, 9].

In 2006, the modified Canadian criteria for BD diagnosis were established and recommended that AT not be performed in patients with chronic hypercarbia and hypoxic respiratory drive. The Canadian criteria also stated that a second series of tests is unnecessary, and when a full clinical evaluation is not possible, the criteria recommend the performance of an instrumental test to determine a lack of brain flow [10].

While AT is being performed, the possibility of complications should be kept in mind. Complications can be due to inefficient baseline blood oxidation, acidosis, arrhythmia and technical issues. Placing the insufflation catheter too deep into the endotracheal tube could lead to unilateral atelectasis, tension pneumothorax, elimination of CO₂ and a slower increase in PaCO₂ level. Tension pneumothorax, pneumomediatinum and pneumoperitoneum have been reported to occur during AT in patients with airway perforation by the insufflation catheter [11, 12].

Patients with a PaO₂ level after preoxygenation of < 200 mm Hg and a SBP of < 90 mm Hg need to be administered catecholamines. Patients with an acid-base balance disturbance (pH < 7.3 or pH > 7.5) or an electrolyte disorder (Na > 170 mEq L⁻¹ or Na < 120 mEq L⁻¹, K > 6.0 mEq L⁻¹ or K < 3.0 mEq L⁻¹, Ca >10.5 mEq L⁻¹ or Ca < 8.0 mEq L⁻¹) are especially vulnerable to the development of hypotension and arrhythmias [13].

Complications emerging during AT complicate BD diagnostics and can lead to cardiovascular destabilization, which results in decreased organ perfusion and, subsequently, organ damage. This is especially important when organs are being considered for transplantation.

In an attempt to determine an appropriate method for conducting AT with a lower risk of complications, Benzel et al. proposed an alternative procedure in 1992. This procedure involved hypoventilation and increasing the baseline PaCO₂ level to a predicted value of 60 mmHg followed by disconnecting the patient from the ventilator for 30-60 seconds and observing chest and diaphragm movements [14].

In 2002, a retrospective study was published that analysed AT performed in 200 patients hospitalized in intensive care units in Buenos Aires. Some patients underwent classical AT — with preoxygenation and subsequent disconnection from the ventilator and oxygen insufflations through the catheter inserted into the endotracheal tube with a flow of 6 L min⁻¹. Some patients underwent an alternative AT — with supply of egzogenic CO₂ to the insufflation tube of the ventilator with the flow of 1 L min⁻¹ for 1 minute, without any modification to the current ventilation parameters. The results of the analysis showed more frequent (33% vs. 14%) serious adverse events (hypotension, cardiac arrest, arrhythmias and hypoxemia) in the group that underwent classical AT compared with the group that underwent the alternative procedure. In conclusion, the authors recommended using this alternative method of AT, especially in patients at risk of serious complications during AT, e.g., patients with an arterial partial oxygen pressure after preoxygenation below 200 mm Hg [15].

In 2004, Saposnik et al. published a retrospective analysis of 129 ATs in Neurology India. They observed adverse events in more than 2/3 of the patients. The analysed group included patients with acidosis indicated by blood gasometry (68%), which significantly increases the incidence of adverse events. Serious complications were noted in 4 patients: pneumothorax, cardiac arrest, bradycardia, atrial fibrillation, and myocardial infarction. The authors concluded that the incidence of complications during AT may be even more frequent than previously reported [16]. In the majority of patients, they noted risk factors of AT, such as acidosis (pH < 7.3), hypotension and hypoxemia. Notably, the causes of BD in these patients were isolated to intracranial patholo-
gies in the form of vascular insufficiency or skull and brain trauma, which should not cause the patient to be in such a bad general state. It is also possible that these complications were related to the low level of performance of the healthcare system. For comparison, in our experience at the Department of Anaesthesiology and Intensive Care Medicine Pomeranian Medical University (unpublished data), the events described by Saposnik et al. were very rare.

Scott et al. [17] performed an analysis of multicentre, retrospective data regarding the incidence of adverse events that emerged during ATs performed between 1992 and 2008, with a total of 608 procedures analysed. Decreased blood pressure and hypoxemia were the most frequent adverse events, and they were noted in 18% and 6% of patients, respectively. In the entire study sample, there were 4 cases of cardiac arrest.

To continue to try to determine the optimal mode of AT, Lévesque et al. conducted a prospective, randomized study [18]. The authors compared the efficacy and safety of 3 methods of AT: the classical procedure, AT with the use of a T-formed tube and AT with CPAP of 10 cm H₂O. They noted that the methods of AT with the use of CPAP or a T-formed tube were safe and could be effective alternatives to the classical method. Additionally, according to the authors, the AT method with CPAP assures the best oxygenation and, therefore, should be particularly useful in patients with oxygenation disturbances.

Wijdicks et al. [19] reviewed the literature regarding BD diagnostics in adults (over 18 years of age) published in Medline between 1996 and 2009. They stated that there is a sufficient amount of evidence regarding the efficacy and safety of an alternative method of AT that uses CPAP, and

![Figure 1. Different variants of CPAP using during AT](image-url)
they recommended its use in cases demanding interruption of classical AT due to instability of the patient. In 2014, Datar et al. [20] published an analysis of the incidence of complications during 76 AT attempts performed at the Mayo Clinic between 2008 and 2012. An unexpectedly low number of complications was observed, possibly because the data were collected from patients with the following baseline parameters after preoxygenation: PaO₂ > 200 mm Hg and pH > 7.32 and the tests were conducted by experienced intensive care specialists. In this study, the ATs were performed using two methods: the classical method with oxygen insufflation and a method with oxygen insufflation using CPAP with a T-formed tube, without determination of how the oxygen insufflation was achieved. The modified guidelines of the American Academy of Neurology from 2010 include this alternative method of AT with the use of CPAP.

In the Poland Supplement to Ministry of Health Announcement published on 17 July 2007 (item 547), the description of the criteria and modes of confirmation of permanent and irreversible cessation of brain function precisely describes AT. As an alternative method in cases of hypoxia resulting from lung injuries, hyperventilation with 100% oxygen was proposed to obtain particular baseline and final values of PaCO₂, i.e., increase CO₂ by at least 20 mm Hg at baseline to achieve a final level of PaCO₂ of at least 60 mm Hg [21].

In the majority of current publications, the authors highlight the need for a uniform method of performing AT that has the lowest risk of complications. It seems that these criteria could be met by using CPAP while supplying AT that has the lowest risk of complications. It seems that

References:
3. A definition of irreversible coma. Raport of the ad hoc Committee of the Harvard Medical School to examine the definition of brain death. JAMA 1968; 6, 85−88.

Corresponding author: Joanna Sołek-Pastuszka
Department of Anesthesiology and Intensive Care Medicine
Pomeranian Medical University Szczecin
ul. Unii Lubelskiej 1, 72–252 Szczecin
e-mail: pastuszka@mp.pl

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