TRANSORALLY OBTAINED OXYGEN TENSION AS AN INDICATOR OF ARTERIAL OXYGEN TENSION

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ABSTRACT. Transcutaneous oxygen electrodes have been used with success in neonates as indicators of arterial oxygenation, but with less success in adults because of differences in skin thickness and vascularity. In this study a prototype transoral oxygen electrode was evaluated to determine if a heated mucous membrane would yield arterialized values of oxygen tension in adults. Using a miniaturized Clark electrode, we measured transoral oxygen tension (PtoO₂) in 29 subjects at steady-state conditions. Simultaneously a sample was anaerobically obtained from a radial artery for measurement of arterial oxygen tension (PaO₂). Data were analyzed using linear regression analysis, Student's t test, and analysis of variance. There was no statistically significant difference between nonwhite and white subjects or male and female subjects. There was a highly significant difference (P < 0.001) between the pooled, matched values for PtoO₂ versus PaO₂, and the regression between the PtoO₂ and the PaO₂ was linear (slope 0.92, y-intercept -8.37, r = 0.62, P < 0.003). The calculated ratio of PtoO₂ to PaO₂ was 0.83 ± 0.03 (standard error). We concluded that the PtoO₂ was linearly related to the PaO₂, although its accuracy in reflecting PaO₂ was low. This finding correlates with previously published data that suggested that the PtoO₂ reflects tissue oxygen tension rather than arterialized oxygen tension. Gender and race appeared not to affect the function of the electrode in our study.


The transcutaneous oxygen electrode, a modification of the polarographic oxygen electrode first described by Clark, was originally conceived as a continuous and noninvasive indicator of arterial oxygenation [1,2]. Arterialization of the capillary bed is achieved by heating the skin to a temperature of 43 to 45°C, causing vasodilatation, increased blood flow, and enhanced oxygen diffusion [1]. Oxygen is reduced at the cathode of the electrode, leading to an electrical potential difference and, therefore, the generation of a current that is proportional to the number of oxygen molecules present. More recently, the measurement of transcutaneous oxygen tension (PtcO₂) has been thought to represent tissue oxygen tension rather than arterial oxygen tension (PaO₂), because the amount of oxygen present at the tissue surface depends on the magnitude of blood flow to the tissue and diffusion of oxygen from the capillary bed to the surface of the electrode. This diffusion may be hampered by differences in skin thickness, tissue vascularity, and tissue oxygen uptake [1,2].

The transcutaneous oxygen electrode, when used in neonates, has yielded a high correlation between mea-
sured PtcO2 values and simultaneously obtained PaO2 values [1,3–5]. Because of the neonate’s increased peripheral vascularity and thin skin, this correlation is high when normal cardiac output and perfusion are maintained [1,5].

The transcutaneous oxygen electrode has been used in adults as an indicator of oxygenation in critically ill patients [6–12] during one-lung anesthesia [13] and bronchoscopic procedures [14], and in the evaluation of peripheral vascular insufficiency [15,16]. However, the transcutaneous continuous measurement of oxygen tension as a substitute for the measurement of PaO2 in adults has been hampered because of perfusion-related variables, such as differences in skin thickness and vascularity [2]. Although high correlation with PaO2 has been achieved in the presence of a normal cardiac output, the accuracy in reflecting absolute PaO2 has been low [6,7,9,17].

To compare PaO2 and PtcO2 measurements, a transcutaneous index, defined as PtcO2/PaO2, has been reported. The average transcutaneous index in adults has been reported to be 0.79 to 0.83 [5,6,8].

In an effort to overcome problems relating to perfusion-related variables, two types of transtissue oxygen electrodes have been devised so that they can be applied to the mucous membranes: the conjunctival and the transoral electrodes [18,20]. The mucous membranes have the theoretical advantage over skin surfaces of being thin and highly vascular, similar to the tissue conditions found in neonates.

The conjunctival oxygen tension electrode has been shown to be useful in adults as a trend indicator of arterial oxygenation [19–22], demonstrating a faster response time than the transcutaneous oxygen electrode [20,22]. Stabilization time is reduced because no heating is required; this is due to the increased vascularity of the palpebral conjunctiva, the absence of a stratum corneum, and a thin epithelial layer [19,23,24]. Because this tissue bed is supplied by the internal carotid artery, the conjunctival oxygen electrode has been used as an indicator of cerebral oxygenation during carotid endarterectomy [25]. Disadvantages of this electrode include the theoretical risk of damage to the eye [26] and the marked variability in the ratio of conjunctival oxygen tension to PaO2, even among healthy individuals [27].

The transoral oxygen electrode was devised to eliminate some of the disadvantages of the conjunctival sensor and still interface with a highly vascular mucosa [18]. In this study, a prototype transoral oxygen electrode was evaluated to determine if heating of mucous membrane surfaces would yield arterialized values of oxygen tension.

### METHODS AND MATERIALS

A recently developed transoral oxygen electrode designed by Ancel Laboratories Corp., Richmond, CA, was evaluated in 29 awake subjects. This sensor was a prototype oxygen electrode not previously evaluated. An oval or lens-shaped electrode backed with soft foam rubber was fitted in the mouth of each subject between the cheek and the teeth. The sensing electrode had a slightly convex structure and came in contact with the inner surface of the cheek. Due to the convex structure of the electrode, slight pressure was exerted on the tissues to maximize contact and to prevent air and salivary secretions from accumulating between the tissue and electrode. The electrode was covered by a rubber sheath that was discarded after each use to prevent cross-contamination. A thin cable led from the edge of this elliptical structure through the mouth to an amplifying console that provided a continuous digital reading as well as a periodic data printout.

The transoral electrode consisted of a central gold disc cathode and a surrounding annular silver anode. A fixed potential difference of 0.60 V was generated between the anode and cathode. An oxygen-permeable polypropylene membrane covered the electrode, and the space between the membrane and electrode was filled with an electrolyte film of buffered potassium chloride solution and ethylene glycol. The sensor was heated to 44.5°C to enhance oxygen delivery from the tissue to the sensor surface. Enhancement of oxygen delivery may be due to improved blood flow to the tissues, enhanced oxygen diffusion in the area of the sensor-tissue interface, or both.

After Human Investigational Review Board approval was obtained, 29 subjects, consisting of 26 healthy volunteers and 3 patients, consented to participate in this study. Normoxic conditions were used in all subjects except 1 man who required supplemental oxygen. The inside of the cheek was washed and gently massaged to enhance blood flow. The transoral electrode was positioned, and a standard dental bite block was fitted to protect the electrical cable. After 20 minutes of equilibration, a steady-state oxygen partial pressure obtained from the buccal surface was recorded. Simultaneously, a radial arterial blood sample was obtained anaerobically in a previously prepared syringe containing dessicated heparin, and immediately placed in an ice slush. Duplicate analysis of the blood sample for oxygen tension was performed after a two-point calibration of an IL 1303 (Instrumentation Laboratories, Lexington, MA) blood gas analyzer. The duplicate analysis of each sample and the quality control measurement were done.