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Journal

Journal of Allergy and Clinical Immunology, 56(1)

ISSN

0091-6749

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Publication Date

1975-07-01

DOI

10.1016/0091-6749(75)90032-9

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Peer reviewed

Capillary pH and blood gas determinations in asthmatic children

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Earlobe capillary pH and blood gases in asthmatic children were compared to arterial values. Hyperemia of the earlobe was produced by applying thurfyl nicotinate (Trafuril). Approximately 15 min later capillary blood was obtained simultaneously with a radial arterial sample. Earlobe capillary PO₂, PCO₂, and pH correlated well with arterial values. This technique is simple, safe, and appears to be a satisfactory substitute for arterial blood in normotensive asthmatic children.

It is well recognized that patients with status asthmaticus are difficult to evaluate and manage adequately without the use of blood gases. Most of these patients are mildly hypoxic and have associated alterations in the pH and PCO₂.¹ Blood for these determinations is usually drawn percutaneously from the radial, brachial, or femoral arteries. At times this is difficult and traumatic, particularly in the very young patient. There are also complications that may be associated with arterial punctures, including pain, temporary loss of pulse, hemorrhage, false aneurysm, and thrombosis with distal ischemia.²

During the past ten years there have been numerous papers in the literature reporting on capillary blood gas determinations.³⁻⁹ From these reports it is clear that the earlobe is superior to the finger, thumb, or heel as a source of arterialized capillary blood and that several conditions, including shock and increased venous pressure, may affect the accuracy of capillary blood gases.³ Many techniques have been used to increase circulation in the capillary bed, such as warm water soaks, heating lamps, iontophoresis, and topical ointments. MacIntyre, Norman, and Smith,⁴ using Trafuril, a cutaneous vasodilator derived from nicotinic acid, have reported that accurate capillary blood gases might be obtained even when the patient's peripheral circulation is compromised. A comparison of arterialized capillary determinations with arterial values has not been reported on in asthmatic patients. It is also not clear if this disease or its treatment alters peripheral circulation and the correlation of capillary and arterial pH and blood gases. The purpose of this study is to determine in asthmatic subjects if capillary blood obtained from the earlobe following induction of hyperemia by the application of Trafuril can be an adequate substitute for arterial sampling in determining pH, PCO₂, and, most importantly, PO₂.

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Received for publication June 4, 1974.

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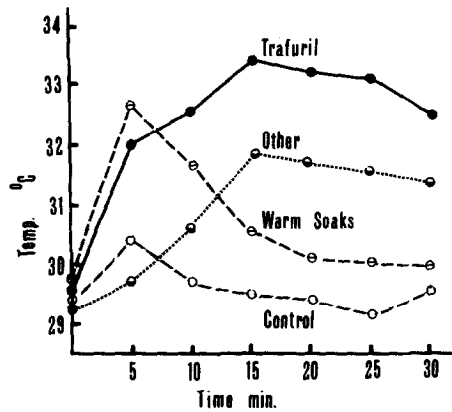


FIG. 1. Graphic representation of skin temperature changes induced by different vasodilating techniques.

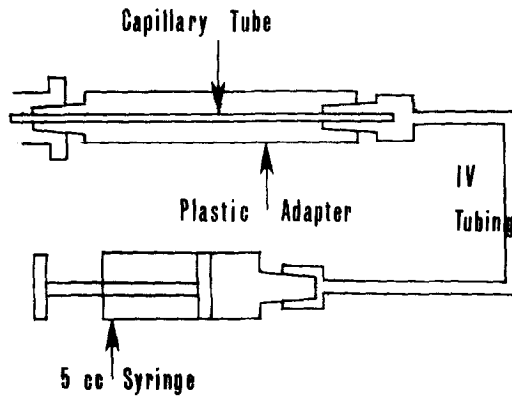


FIG. 2. Plastic adapter used in the determination of capillary blood gas samples.

MATERIALS AND METHODS

Comparison of methods for inducing hyperemia

Five normal adults whose skin temperature had equilibrated with a constant environmental temperature were used in these evaluations. Four methods for inducing hyperemia were compared (Fig. 1): application of warm water soaks (45° C) for 5 min; massage of the earlobe for 1 to 2 min (control); application of Trafuril by massage for 1 to 2 min; and application of several preparations containing oil of wintergreen, camphor, and histamine by massage for 1 to 2 min (other). Skin temperature, which has been shown to correlate with cutaneous blood flow,¹⁰ was recorded at 0, 5, 10, 15, 20, 25, and 30 min following the application of these methods. Earlobe temperature was measured with a skin thermistor (Tele-Thermometer, Yellow Springs Instrument Co.).

Capillary tube adapter

A plastic adapter (Fig. 2) was made to give support to the capillary tube and to facilitate removal of blood. This adapter is 10.8 cm long with an internal bore diameter of 1.5 mm. The male end is attached to the blood gas analyzer (Instrumentation Laboratory, Inc., Model 113). The capillary tube containing the blood sample is slid into the open end of

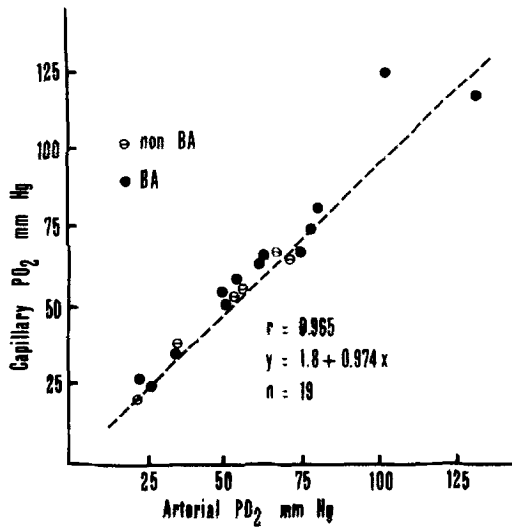


FIG. 3. Correlation between earlobe capillary and arterial PO₂ values. **BA** (closed circles) represents subjects with bronchial asthma and **non BA** (open circles) represents subjects with other lower respiratory problems.

the adapter, and a short piece of intravenous tubing connected to a small syringe is then attached. Air pressure from a syringe allows controlled emptying of the blood into the blood gas analyzer. Following PO₂ and PCO₂ determinations, this blood may be removed by negative pressure from the syringe for pH determination.

Capillary blood gas determination

Nineteen determinations were made on 11 children (ages 1 to 13) with status asthmaticus and 5 patients (including 3 adults) with pneumonia. All of these patients were normotensive. Trafuril was applied to the earlobe and massaged gently for 1-2 min. Approximately 15 min later a radial arterial sample was drawn percutaneously in a heparinized (1,000 U sodium heparin/cc) glass syringe. Simultaneously, a 2-3 mm incision was made with a No. 11 Bard-Parker scalpel blade in the lower portion of the earlobe, and 2 heparinized (1,000 U sodium heparin/cc) capillary tubes were filled quickly by capillary action. The blood specimens were placed on ice and analyzed within a few minutes of collection on a pH/gas analyzer utilizing the plastic adapter as described previously. PO₂, PCO₂, and pH were calibrated at two points using standard methods.

RESULTS

Comparison of methods for inducing hyperemia

Trafuril produced a 4° rise in earlobe skin temperature, which reached a maximum at approximately 15 min. It should be noted that the temperature elevation was persistent for at least 30 min. The materials containing oil of wintergreen, camphor, and histamine all had similar effects on skin temperature and are presented in a curve designated as "other." All of these substances were less effective in producing hyperemia than Trafuril. An initial increase in temperature was seen with warm water soaks, and it fell off rapidly. Massage

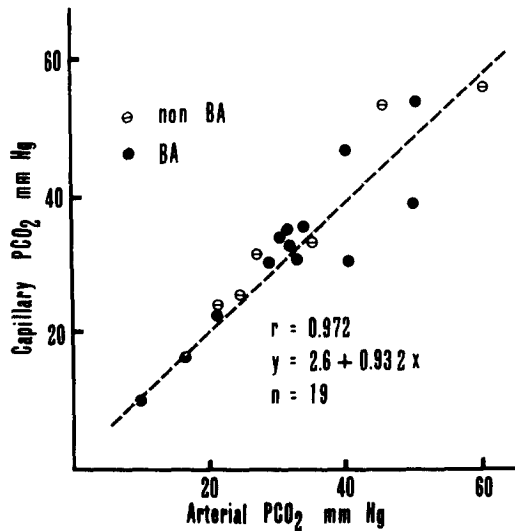


FIG. 4. Correlation between earlobe capillary and Arterial PCO_2 values. **BA** (closed circles) represents subjects with bronchial asthma and **non BA** (open circles) represents subjects with other lower respiratory problems.

of the earlobe alone was used as a control. It resulted in a small and transient increase in skin temperature.

Correlation between capillary earlobe and arterial blood gases and pH

The coefficient of correlation between arterial and capillary earlobe blood PO_2 was 0.965 ($p < 0.005$) with a standard error of estimation of ± 6.8 (Fig. 3). The coefficient of correlation between arterial and capillary earlobe blood PCO_2 was 0.972 ($p < 0.005$) with a standard error of estimation of ± 4.2 (Fig. 4). The coefficient of correlation between arterial and capillary earlobe pH was 0.987 ($p < 0.005$) with a standard error of estimation of ± 0.08 (Fig. 5). These values were calculated from 19 points obtained in 11 asthmatic and 5 nonasthmatic patients.

DISCUSSION

In comparing methods of inducing hyperemia, we found that Trafuril was clearly superior to other topical preparations. Some methods such as warm water soaks will create a significant temperature rise; however, it is relatively brief, and therefore the sample must be obtained quickly if the blood is to be representative of an "arterialized" capillary bed. Trafuril appears to have a number of significant advantages: it is easy to apply; its persistent effectiveness allows ample time to obtain the capillary sample; it is safe; and, most importantly, it provides excellent correlation between capillary and arterial blood gas and pH values.

PCO_2 and pH in venous blood are very close to arterial levels, and therefore

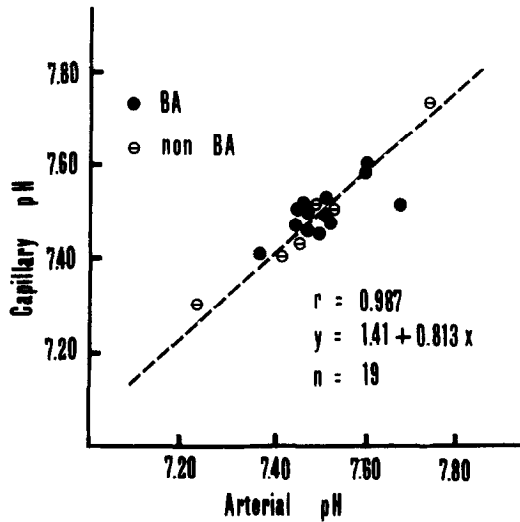


FIG. 5. Correlation between earlobe capillary and arterial pH values. **BA** (closed circles) represents subjects with bronchial asthma, and **non BA** (open circles) represents subjects with other lower respiratory problems.

capillary sample with arterial-venous mixing may still provide acceptable values in many instances. However, because of the large A-V PO_2 difference, capillary specimens with arterial-venous mixing will not give an accurate approximation of arterial PO_2 values. Accurate capillary PO_2 determinations depend upon variables that minimize this A-V difference in O_2 saturation, such as low oxygen consumption and a high perfusion rate. The earlobe's superiority as a capillary bed may be related to these factors. Most investigators have found that shock with the accompanying decreased perfusion makes capillary PO_2 values unreliable. However, MacIntyre, using Trafuril on the earlobe, found that capillary PO_2 may remain acceptable even with reduced blood pressure. Our data on normotensive asthmatic patients do not clarify this question. At this time, it is best to interpret capillary PO_2 values carefully in hypotensive patients.

We are hopeful that this simple and accurate technique will improve patient care. Most physicians at some time have neglected blood gas determinations to the detriment of the patient, primarily because of the difficulty in obtaining them. Our method may change this effectively by making accurate capillary blood gas determinations a nursing procedure.

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