A Modified Platinum Electrode Method for Cardiac Diagnosis

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The platinum electrode sensing devices originally described by Clark and Bargeron¹ in 1959 provide a simple, rapid and reproducible means of detecting and localizing intracardiac shunts. Their clinical application has been well documented in the past five years.² This paper will describe a modification of the platinum electrode and its application and a modification of the method of hydrogen gas administration. The advantages of these modifications will be discussed.

The potentiometric electrode: Clark and Bargeron¹ applied the classic hydrogen reference electrode principle to the measurement of gaseous hydrogen concentration in the blood. Platinum electrodes coated with platinic chloride (platinized) were found to produce potentials up to 300 mv with reference to a silver skin electrode upon exposure to blood containing hydrogen gas. These potentials exceed the normal cardiac potential and can be measured and recorded by conventional DC amplifiers and recording devices. This electrode provides a sensitive method for the recognition of both left-to-right and right-to-left intracardiac shunts. In the detection of left-to-right shunts, inspired hydrogen gas is dissolved in blood as it passes through the lungs to enter the left heart. From there, part of the hydrogen-containing blood then enters the right heart through the defect and activates the platinized platinum electrode positioned there earlier than would occur in the normal individual. The potential developed is in the range of 100 mv and the appearance time is usually less than one second after hydrogen dose administration.

In the detection of right-to-left shunts, Clark et al.³ injected hydrogen-saturated saline into the right heart and monitored for hydrogen in the aorta with the platinized platinum electrode. This technique is based on the observation that hydrogen is completely cleared from intravenously injected hydrogen-saturated saline as it passes through the normally ventilated lungs. Incidentally, it was observed that a platinized platinum electrode also develops a recordable potential in the presence of sodium ascorbate. Hence ascorbic acid can be used as an indicator for right-to-left shunts with the platinized potentiometric electrode and can also be used for verification of the function of the detecting electrode.

Polarographic electrode: The platinum electrode is referred to as a polarographic electrode whenever it is polarized as either a cathode or an anode and must, therefore, be distinguished from the potentiometric electrode method. The polarographic cathode is a familiar instrument to the biologist for measuring oxygen whereas the polarographic anode is a more recent development⁴ and is used in the detection of right-to-left shunts. As a polarographic anode, the electrode readily oxidizes certain

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¹From the Latter-day Saints Hospital.
²The Donald Guthrie Foundation, Sayre, Pennsylvania.
substances such as ascorbic acid, and this oxidation produces a minute measurable current. In applying the polarographic method, the electrode is positioned in the central aorta, or in a peripheral artery, and ascorbic acid is then injected in the chambers of the right heart. In the presence of a right-to-left shunt, ascorbate enters the arterial circulation prematurely through the right-to-left shunt and is immediately detected by the electrode in the aorta. Since ascorbate is not eliminated in the lungs, a late curve indicating normal pulmonary circulation of the agent appears in about five seconds. The right-to-left shunt is localized by identifying the right heart chambers from which the ascorbate injection produces an immediate polarogram. The polarographic electrode method is

Figure 1: Platinum electrode. The electrode consists of a Teflon covered multiple strand copper wire 27/1000 inches in diameter. The platinum cap is secured by solder and by crimping it around the insulation. The electrode can readily be inserted through standard cardiac catheters 5F, 6F and 7F.

Figure 2: Hydrogen administrator. This hollow hydrogen gas administrator contains an electrode assembly in the barrel which records the instant of dose administration. Hydrogen gas is admitted selectively by depressing the "trigger" valve in the handle. The electrode assembly may be removed for cleaning and replatinizing. Multiple barrels are available to accommodate both children and adults.
preferable to the potentiometric electrode in the diagnosis of right-to-left shunts because it is a more sensitive method.

**Methods and Materials**

**The modified sensing electrode:** The essential characteristics of platinum intracardiac electrodes used with potentiometric and polarographic circuits are that a free platinum surface be exposed to the circulating blood and that the electrode be freely mobile for selective positioning. The sensing electrodes described in this report (Fig. 1) are made by placing a platinum cap over the end of a Teflon-insulated multiple strand copper wire. The platinum cap is secured by soldering it to the copper wire, and this connection is sealed by crimping the platinum cap on the Teflon insulation. Electrical connection to the potentiometric or polarographic circuit is made by a simple unipolar jack. The sizes of these platinum electrodes vary to accommodate their passage through thin-walled 5F, 6F and 7F cardiac catheters and to prevent leakage of blood around the electrode. Larger electrodes (50/1000 inches diameter) were designed for use as a polarographic anode and can be passed through the arterial system independent of a cardiac catheter. All of the electrodes described can be platinized in the standard way.

**Modified hydrogen administrator:** The clinical value of the hydrogen dilution curves depends upon the accurate measurement of hydrogen circulation time in the central circulation. Since the response of platinum electrodes to hydrogen is for practical purposes instantaneous, the accuracy of this measurement is limited by the precision with which the hydrogen administration time can be recorded. A device (Fig. 2) for more precise timing of hydrogen administration was developed by one of us (H.C.R.) to produce a dose-time signal at the same instant it delivers the gas.

**Figure 3:** Hydrogen dilution curve. A 12-year-old child with VSD and 2.0 liter left-to-right shunt. The electrode in pulmonary artery and right ventricle demonstrate the left-to-right shunt by a hydrogen curve occurring 2.5 seconds after the test dose administration. In right atrium, the hydrogen curve appears after normal circulation of the dissolved gas in seven seconds. These curves identify the left-to-right shunt to exist at the ventricular level. Time lines equal one second.
to the patient's airway. This device is made in the form of a hollow pistol through which the patient can breathe freely. The handle of the instrument contains a manually operated one-way valve through which hydrogen is selectively administered to the patient. An electrode assembly consisting of a platinized platinum electrode and a silver reference electrode are contained in the muzzle. These two electrodes are separated by a saline soaked cellophane barrier and are connected to a DC amplifier by a two-pole jack. When hydrogen gas is administered to the patient, it must pass this electrode assembly where a potential is developed that instantly signals the dose time. Administration of the hydrogen dose can be given coincident with inhalation after brief observation of the patient's respiratory pattern. The electrode assembly is so located in the muzzle of the instrument that if a mistake in timing of the hydrogen dose occurs, the hydrogen is carried out through the butt of the instrument with the stream of expired air and no dose signal will be produced.

DISCUSSION

Platinum electrodes applied in cardiac diagnosis with hydrogen and ascorbic acid dilution studies provide a rapid, reproducible, dependable and simple method for recognition of intracardiac shunts. The hydrogen curve is a more sensitive index of the left-to-right shunt than indo-cyanine green dye and it is considerably more sensitive than oxygen determinations. Both the potentiometric and polarographic systems require less complicated and less expensive equipment for their operation than any other method for identifying intracardiac shunts. Furthermore hydrogen and ascorbic acid curves are more dependable than oxygen data in uncooperative patients, the test agents are biologically harmless, and these techniques obviate the need for extensive blood sampling. Some precautions should be observed, however, when using the platinum electrode technique. There is an explosion hazard with the use of hydrogen which for practical purposes is not a serious one, and the risks that exist can be minimized by the use of small tanks of the

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**Figure 4:** Ascorbic acid dilution curve. This eight-year-old child with AV communis, pulmonary hypertension, was severely cyanotic. Ascorbic acid dilution curves demonstrate right-to-left shunt at the ventricular level. In the pulmonary artery tracing, the dose was administered at the beginning of the first time—signal above the tracing. The ascorbate curve appears 2½ seconds later indicating the normal circulation time through the lungs. In the right ventricular tracing, a right-to-left shunt is demonstrated with the instant of ascorbate injection and is shown as the immediate downward deflection of the tracing. A pulmonary circulation curve follows 3½ seconds after dose administration. Time lines equal one second.
gas and two-stage pressure reducing valves. The risk of electrocution is a more serious hazard which can be controlled by using a common ground for electrical equipment in contact with the patient and by leaving the reference skin electrode ungrounded. Quantitation of the hydrogen and ascorbic acid dilution curves is still a problem, although Hyman has described a linear system for quantitating hydrogen curves.

The modified electrode which is described here has certain advantages over the presently available electrodes. Clark and Bargeron's original electrode consisted of a catheter in which the lumen was obliterated by the platinum tip, and it could therefore not be used for pressure measurement or for collection of blood samples. Commercially available platinum electrodes which are constructed in standard cardiac catheters have the disadvantages of increased cost and limited durability. The modified electrode described here is made in graded sizes for use in conjunction with any standard thin-walled cardiac catheter size 5F to 7F. The electrode is sufficiently rigid to be readily inserted through its respective catheter, yet is pliable enough to avoid tissue injury. With this advantage, it is possible to use a standard cardiac catheter in the usual way for intracardiac diagnosis and by simple insertion of the electrode through the catheter, to obtain hydrogen or ascorbic acid curves repeatedly at various places in the central circulation. A single electrode has been used for hydrogen studies in over 120 consecutive catheterizations without evidence of electrode deterioration. The larger modified electrodes can be independently manipulated in the arterial system for use as polarographic anodes. They can be inserted either percutaneously or by cutdown and since they do not occlude the artery, arterial blood can be sampled if desired at the same site. This electrode has the particular advantages of small size and independent maneuverability which is important in children whose small arteries present technical problems in catheterization.

Platinum needles have been used as polarographic anodes; however, they commonly make contact with the atrial wall thus prematurely completing the circuit. The platinum tip of the modified electrode is less apt to contact the arterial wall because it lies freely in the artery and is therefore a more dependable electrode than the needle.

The modified hydrogen administrator was specifically designed to overcome some of the problems inherent in the methods most commonly described for recording the critical hydrogen administration dose time. The signal produced by nasal electrodes was often unsatisfactory because the electrodes were too easily displaced, and often became covered with mucus so that no signal was produced. In children, these electrodes were poorly tolerated because they were both uncomfortable and frightening. The manual dose time signal depends on the reaction time of the operator and is satisfactory only in very experienced hands. An hydrogen electrode inserted in a peripheral artery is sometimes used to signal the dose time; however, it introduces the unnecessary potential hazards of arterial injury, infection, inconvenience and pain which can be modified by utilizing the simpler external means for recording dose time. The modified hydrogen administrator described here has the advantage of consistently producing a dependable dose time signal whenever the patient inhales hydrogen. Because it is entirely an external device it is not uncomfortable and frightening to patients, and the platinum electrode within it cannot be covered with mucus or secretions. A false positive signal can occur when the patient initiates inspiration but stops inhaling before hydrogen actually enters the airway. This event can be recognized by the absence of a circulation signal from intracardiac electrode. The modified hydrogen administrator is a durable device that can be repeatedly used without significant deterioration, and it requires no special handling and maintenance. The platinum electrode within it can be removed easily for replatinizing.
and a technician can maintain and clinically apply this instrument. It has been satisfactorily applied clinically for more than three years.

**Summary**

A modified platinum electrode method for detection of cardiac shunts is presented. A modified electrode and modified method for hydrogen gas administration are described with discussion of the advantages and disadvantages of this new method. Examples of the clinical application of the technique are presented.

**Resumen**

Presentamos un electrodo de platino modificado para revelar la existencia del shunt cardíaco.

Describimos un electrodo modificado y un método para la administración de gas hidrógeno, con comentarios sobre sus ventajas y desventajas. Exponemos algunas de las aplicaciones clínicas de esta técnica.

**Résumé**

Une méthode modifiée avec une électrode en platine pour la détection des shunts cardiaques est présentée. Une électrode modifiée, et une nouvelle méthode pour administration d'hydrogène, sont décrites avec la discussion des avantages et des inconvénients de cette nouvelle méthode. Des exemples de l'application clinique de la technique sont présentés.

**Zusammenfassung**


**References**


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