Original Research

A New In Vivo Method for the Direct Measurement of Nutrient Artery Blood Flow

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ABSTRACT

A new method of directly measuring nutrient artery blood flow using ultrasonic probes is described. These probes have provided reproducible results in our experiments. Advantages of ultrasonic probes include the direct measurement of blood flow through small arteries, ease of use, accuracy of measurement, applicability to a wide range of vessel diameters, the capability of chronically monitoring blood flow over time using permanently implanted probes, and the ability to use the method in conjunction with previous methods of bone blood flow measurement. The method is limited to the extent that only the contribution of the nutrient artery can be measured and total bone blood flow cannot be assessed. Tibial nutrient arterial flow and cardiac output were measured in adult mongrel dogs. Two experiments were performed: 1) bilateral baseline tibial nutrient artery blood flow measurements over time and 2) tibial nutrient blood flow comparing inhaled anesthesia (halothane/nitrous oxide/oxygen) and intravenous anesthesia (pentobarbital [Nembutal]).

In 15 mongrel dogs, tibial nutrient artery blood flow averaged 1.46 ± 0.72 mL/min (0.09 ± 0.05 percent of cardiac output and 2.75 ± 1.95 mL/min/100 g of bone). No significant difference in tibial nutrient artery blood flow was observed between animals given intravenous and inhaled anesthesia ($P>.05$). As a basic research tool, transit-time ultrasonic blood flow technology may be useful. The method is relatively easy to use and may be applied to experimental models designed to investigate various physiologic and pathologic states frequently encountered in orthopedics (eg, shock, sepsis, fractures).

The blood supply to bone has proven to be difficult to fully characterize. Many methods have been devised to study various aspects of bone circulation (anatomy, physiology, and pharmacology), yet no single method has proven to be universally acceptable to study a wide range of blood flow problems in experimental animals. Whereas one method may be well-suited for a particular study, an application of the same method to another experimental problem may be grossly inadequate. The ideal method for the study of bone blood flow should: 1) be as noninvasive as possible, 2) measure the contribution of all vascular channels to bone blood flow, 3) distinguish between the contribution of each vascular channel to bone blood flow, 4) measure flow directly and dynamically, 5) be compatible with other systems of bone blood flow measurement, 6) be capable of measuring blood flow chronically (over weeks to months), and 7) be relatively easy to use.

Of the numerous methods developed to study bone blood flow, the vast majority rely on indirect measurements of actual changes in flow. These methods may be grouped into roughly 11 categories with variations in each category. Table 1 illustrates the indirect methods of bone blood flow measurement and the limitations of each method.

In contrast to the wide variety of indirect measurements of bone blood flow, only four methods have previously been described that directly measure blood flow: vital microscopy,[1] electro-

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