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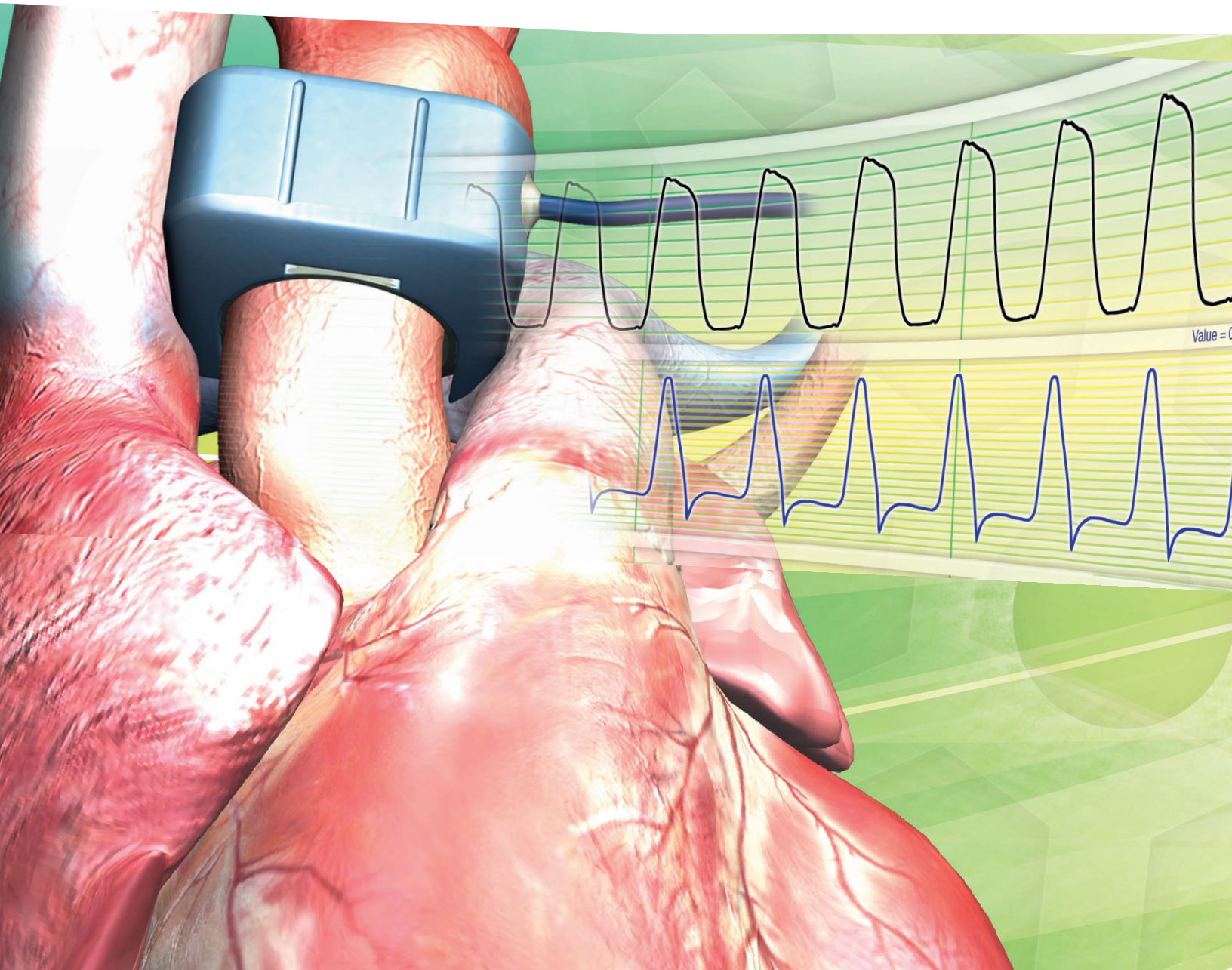
Flow Measurements in Large Animal Models Workbook



This workbook presents a historical collection of protocols, data tables and graphs, tricks-of-the-trade and application support for successful hemodynamic measurements using transit-time volume flow technology. It is designed to showcase the diversity of transit-time flow studies in large animals. Note: Proper implementation of the techniques discussed here are always done in concert with your institutions own best practices. Appropriate surgical procedure, accurate collection and interpretation of data is the responsibility of the researcher.

This workbook is a living document that we will continue to change over time due to technological improvements, new surgical approaches, and the exploration of new applications. Nevertheless, we believe that this workbook, in its current form, will serve to advance the measurement of better results for you.

We appreciate the feedback of our many customers whose studies form the foundation for the included application protocols and whose quest for solid scientific data continues to stimulate ongoing product improvements.

This handbook is an educational service provided by Transonic Systems Inc.®,
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Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells "gold standard" transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.

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Table of Contents

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Table of Contents

Introduction

Dear Fellow Researcher,

Thank you for trusting Transonic's resources and technology to conduct your research. Transonic has been working with life science researchers for over 35 years. During that time a lot has changed in the field of animal research. Surgical approaches have been refined, anesthesia and pain protocols have been optimized, specialty surgical tools have been developed. Some things don't change so much, our in vivo transit-time ultrasound technology. In this workbook, we have created a compilation of equipment information and surgical protocols used in blood flow measurements in large animal models over the past 35-years. This book should be seen as an inspirational companion piece to other workbooks and manuals, to help integrate our products into your laboratory and hopefully entice new experiments. We believe strongly that education bridges the gap between aspiration and application. To facilitate our vision, we have always worked closely with customers, helping to develop and document ground-breaking advances – something we are excited to share with the world. Our literature covers not only product information, but also application details (such as surgical tools and techniques), technology workbooks, scientific blogs and webinars presented by distinguished researchers.

In this Large Animal Blood Flow Workbook we will review the information and the knowledge collected over the years through our collaborative efforts, with a focus on several large animal models used in cardiovascular research. We will start with reviewing Transonic's transit-time ultrasound technology theory and development. Next, we will present the equipment components required for flow measurement and how to set-up, test, and use them. Finally, we will share a collection of surgical protocols conducted in various large animal models. The reader might notice, that unlike our other workbooks, we have not included information about surgical tools, perioperative regimens, or anesthesia. Since large animal surgery is significantly more complex than small animal procedures and much has improved and has been developed over the past 35-years, the entirety of this information is highly specific to species, surgery, and protocols. Therefore, it should not be sourced from this workbook but entirely from institutional and animal welfare agencies' guidelines and resources. Transit-time ultrasound is the gold standard for volume flow measurement due to its reliability, stable offset at zero flow and overall accuracy for in-vivo blood flow applications, and therefore is aligned with Refinement and Reduction in the Principles of the 3R's. Our hope is that this workbook will provide useful information about flow measurements in different species and vessels, therefore expanding the possibilities for your current or future protocols. We are proud to have always been so involved in helping users achieve the ultimate goal of any given experiment, which is accurate data collection, as we understand the bulk of the work lies with the researcher. We hope this partnership between Transonic and customers continues to grow and that this growth can be reflected in future expanded versions of this book.

Sincerely,

The Transonic Research Team


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Margo Sosa


Filip Konecy

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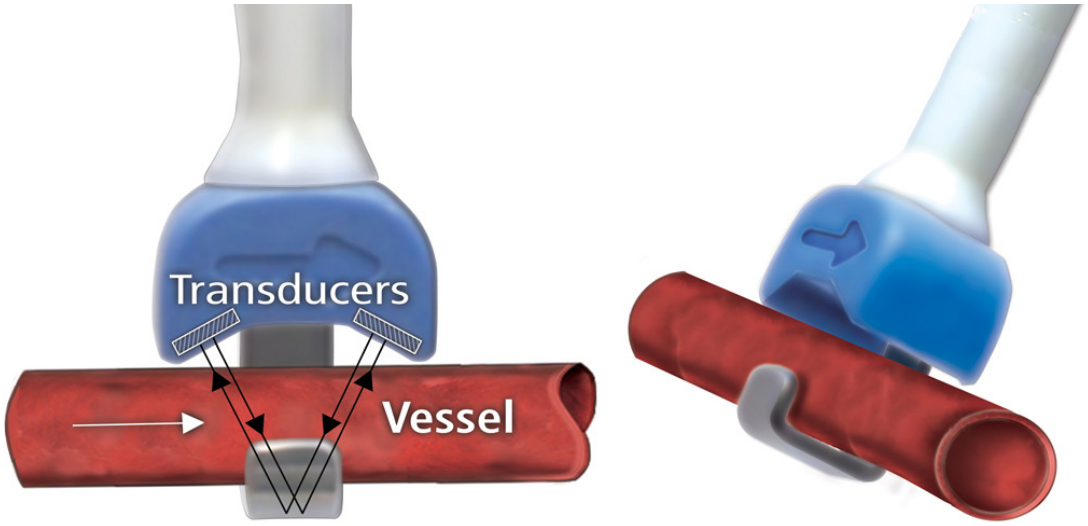
Volume Flow - Technology



Understand the concepts of volume flow technology and how it compares to other methods used for flow measurement.

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Introduction to Transit-Time Ultrasound Volume Flow Measurement

Blood flow refers to the movement of blood through a vessel, tissue, or organ, and is usually expressed in terms of volume of blood per unit of time (mL/min or L/min). It is initiated by the contraction of the ventricles of the heart. Ventricular contraction ejects blood into the major arteries, resulting in flow from regions of higher pressure to regions of lower pressure, as blood encounters smaller arteries and arterioles, then capillaries, then the venules and veins of the venous system. Blood supply is critical for life as it provides nutrients and oxygen to organs and tissue. Blood flow and blood pressure are strongly related, however measuring one does not automatically correlate to changes in the other.

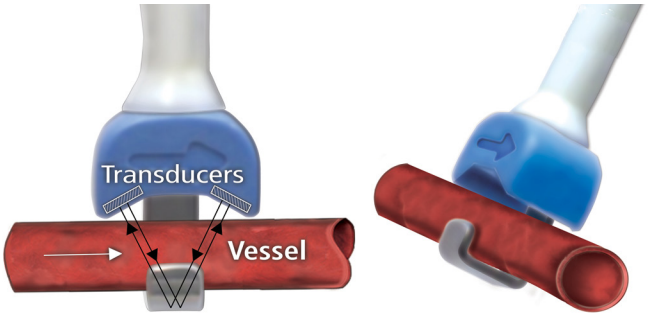
The search for a better method for blood flow measurement was undertaken by Transonic founder Cornelis (Cor) Drost at the NYS Veterinary College at Cornell over 40 years ago. Working under the direction of Dr. Alan Dobson, professor of Physiology, Mr. Drost figured out how to measure the amount of blood flowing through blood vessels in a manner where one would not have to interfere with the flow inside the vessel itself.

In 1978, the group presented this theoretical breakthrough to the world. The technology used differential transit-time of upstream and downstream ultrasound signals to measure volume flow of blood directly from outside the vessel wall. Its revolutionary aspect was that it measured the actual volume of blood (rather than the blood velocity that Doppler systems measured) flowing through the vessel with high accuracy and without having to do things to the vessel that would change the very flow that one would want to measure. Transit-time ultrasound quickly became the gold standard for volume flow measurement due to its reliability, stable offset at zero flow and overall accuracy for in vivo blood flow applications in arteries, veins and even extracorporeal tubing.

Transonic's flow measurement technology development and application in the scientific field started in large animals, such as cattle with Flowprobes larger than 10 mm. Through collaboration with pioneering researchers, Transonic worked to miniaturize a small 1 mm Flowprobe that could be used to measure renal blood flow in a rat. In 1990, the T106 and T206 Small Animal Flowmeters were introduced to the research community. By 1999, a tiny 1.5 mm mouse ascending aorta Flowprobe was available; followed in 2000 by 0.7 mm and 0.5 mm Flowprobes. The T106 and T206 have been retired for many years now and the successor the TS420 Perivascular Flowmeter can be found in many labs worldwide. These days the largest perivascular Flowprobe designed for a large ascending aorta is our 36 mm PAU probe. Many of the non-invasive clinical blood flow technologies available today have been validated in large animal studies using Transonic research Flowprobes as the gold standard. Through Transonic's tradition of collaboration with pioneering research scientists, we have been able to address the ever challenging pursuit to resolve blood flow measurements with finer precision and accuracy and make those techniques available to the scientific community.

Transit-Time Ultrasound Technology Theory of Operation

A Transonic Perivascular Flowprobe consists of a probe body which houses two ultrasonic transducers and a fixed acoustic reflector, or four ultrasonic transducers. The probe body is placed around the vessel under study resulting in the transducers being positioned on one side of the vessel and the reflector is positioned at a fixed position between the two transducers on the opposite side, or two transducers on either side of the vessel. Electronic ultrasonic circuitry directs a Flowprobe through the following cycles, where a four-transducer design creates a more sensitive measurement compared to a two-transducer and reflector combination:



Using wide beam illumination, two transducers pass ultrasonic signals back and forth, alternately intersecting the flowing liquid in upstream and downstream directions. The Flowmeter derives an accurate measure of the "transit-time" it takes for the wave of ultrasound to travel from one transducer to the other. The difference between the upstream and downstream integrated transit-times is a measure of volume flow rather than velocity.

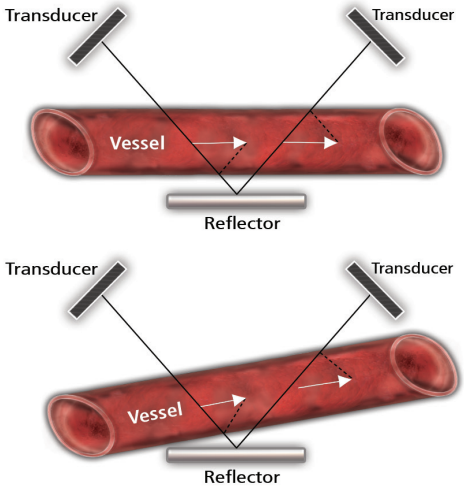
UPSTREAM TRANSIT-TIME MEASUREMENT CYCLE

An electrical excitation causes the downstream transducer to emit a plane wave of ultrasound. This wave intersects the vessel under study in the upstream direction, then bounces off the fixed "acoustic reflector." It again intersects the vessel and is received by the upstream transducer where it is converted into electrical signals. From these signals, the Flowmeter derives an accurate measure of the "transit-time" it takes for the wave of ultrasound to travel from one transducer to the other.

DOWNSTREAM TRANSIT-TIME MEASUREMENT CYCLE

The same transmit-receive sequence is repeated, but with the transmitting and receiving functions of the transducers reversed so that the flow under study is bisected by an ultrasonic wave in the downstream direction. The Flowmeter again derives and records from this transmit-receive sequence an accurate measure of the transit-time it takes for the wave of ultrasound to travel from one transducer to the other.

Just as the speed of a swimmer depends, in part, on water currents, the transit-time of ultrasound passing through a conduit is affected by the motion of liquid flowing through that vessel. During the upstream cycle, the sound wave travels against flow and total transit-time is increased by a flow-dependent amount. During the downstream cycle, the sound wave travels with the flow and total transit-time is decreased by the same flow-dependent amount. Using wide beam ultrasonic illumination, the Flowmeter subtracts the downstream transit-times from the upstream transit-times. This difference in the integrated transit-times is a measure of true volume flow.



The ultrasonic beam intersects the vessel twice on its reflective path. With each intersection, the transit-time through the vessel is modified by a vector component of flow. The full transit-time of the ultrasonic beam senses the sum of these two vector components. With misalignment (bottom), one vector component of flow increases as the other decreases, with little consequence to their sum.

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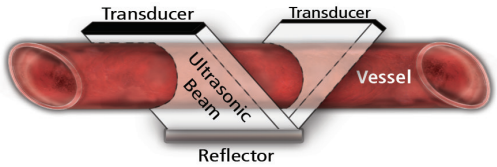
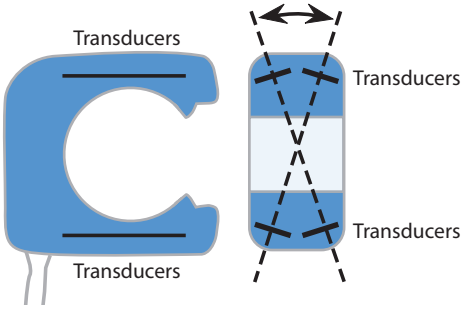
Transit-Time Ultrasound Theory of Operation Cont.

WIDE BEAM ILLUMINATION

One ray of the ultrasonic beam undergoes a phase shift in transit-time proportional to the average velocity of the liquid times the path length over which this velocity is encountered. With wide-beam ultrasonic illumination, the receiving transducer integrates these velocity-chord products over the vessel's full width and yields volume flow: average velocity times the vessel's cross sectional area. Since the transit-time is sampled at all points across the vessel diameter, volume flow measurement is independent of the flow velocity profile. Ultrasonic beams which cross the acoustic window without intersecting the vessel do not contribute to the volume flow integral. Volume flow is therefore sensed by Perivascular Flowprobes even when the vessel is smaller than the acoustic window.



The vessel is placed within a beam that fully and evenly illuminates the entire blood vessel. The transit-time of the wide beam then becomes a function of the volume flow intersecting the beam, independent of vessel dimensions.



COnfidence Flowprobes® use four transducers to create an X-beam ultrasonic illumination pattern to achieve a full vessel volume flow measurement.

REFERENCES

1. Drost, C.J., "Vessel Diameter-Independent Volume Flow Measurements Using Ultrasound", Proceedings San Diego Biomedical Symposium, 17, p. 299-302, 1978.
2. U.S. PATENT 4,227,407, 1980.

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The Challenge of Flow Measurement

We are sometimes asked why top quality Flowsensors have an absolute accuracy of 10-15% when even disposable pressure transducers have accuracy specifications of 1% or better. The answer lies in a brief review of fluid mechanics.

PRESSURE

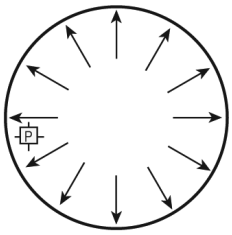


Fig. 1: Pressure

Pressure is a scalar quality associated with the potential energy of a fluid. It is expressed in units of force per area. It does not have direction. Since it is an energy measurement, pressure equilibrates and varies only slightly across a vessel's cross section. These characteristics permit adequate blood pressure measurements with a point sensor.

VELOCITY

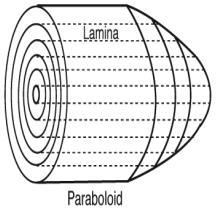


Fig. 2: Laminar Flow Profile

Velocity is a vector quantity associated with movement. It is expressed in units of distance per time (m/min, cm/sec). Velocity has direction. Measurement of velocity is very sensitive to the alignment between the vessel and the sensor. In hemodynamic applications, measuring the average velocity is complicated by variations in velocity across a vessel. In most vessels, blood velocity increases as its distance from the vessel wall increases to create a parabolic laminar flow profile (Fig. 2).

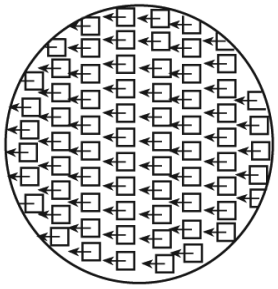


Fig. 3: Integration over entire area of vessel

To accurately measure average flow from flow velocity requires a sensor that can integrate the velocities over the entire area of the vessel (Fig. 3). In practice, many velocity Sensors only measure the maximum velocity at the center of the vessel and assume a parabolic laminar profile (Fig. 4). Other Sensors measure the local velocity at several points and assume a rotationally symmetrical profile (Fig. 5).

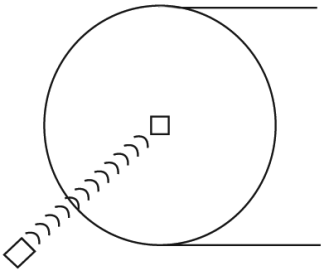


Fig. 4: Continuous Doppler: peak velocity measurement.

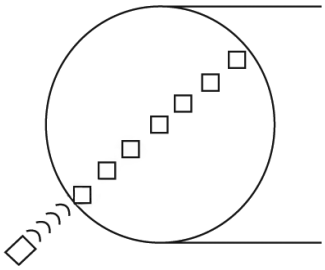


Fig. 5: Pulse Doppler: measures local velocity at several ranges.

FLOW

Flow is a vector quantity associated with the movement of mass. It is expressed in units of "mass flow" or "volume flow". Flow, like velocity, has direction.

Volume flow can also be expressed as a product of average velocity and area. Since both terms are vectors, the velocity term must actually be the component of velocity perpendicular to the plane of the area.

In hemodynamic applications, both the area and the velocity are continually changing. This complicates measurement. Volume Flowsensors are usually integrating devices that are sensitive to changes in local velocity over the entire area of the vessel. A perfect Flowsensor is uniformly sensitive to changes in velocity over the entire cross-sectional area of the vessel. It is also fully insensitive to changes in cross sectional area of the vessel.

Both electromagnetic and transit-time ultrasound Flowsensors are integrating volume Flowsensors. Both devices respond to local changes in blood velocity anywhere within the vessel. However, neither device is "perfect" as it is currently impossible to build Flowsensors with a truly uniform sensing field.

The Challenge of Flow Measurement Cont.

ELECTROMAGNETIC FLOWSENSORS

With an electromagnetic Flowsensor, flow sensitivity is greatest in the area of the vessel closest to the electrode. This flow sensitivity is also affected by the conductive properties of the vessel wall and electrical couplant. Consequently, electromagnetic Flowsensors require a tight fit around the vessel.

TRANSIT-TIME ULTRASOUND FLOWSENSORS

In contrast, transit-time Flowsensors can be used with a loose, non-constrictive fit around a vessel, since vessel-wall and acoustic couplant are integrated into the volume flow measurement. Transit-time ultrasound Flowsensor measurements show a variation in field sensitivity in only one dimension. This approximates the contour of a loaf of bread. The flow sensitivity pattern and insensitivity to wall effects allow the transit-time Flowsensors to measure flow over a range of vessel sizes.

However, since the ultrasonic illumination is not completely uniform, an error range in absolute accuracy exists. This is demonstrated by Fig. 6 where an ideal calibration line has the equation Y = X. In practice, there are small deviations from perfection in the slope and offset. The actual equation is Y = A + BX, where A is the offset and B is the slope.

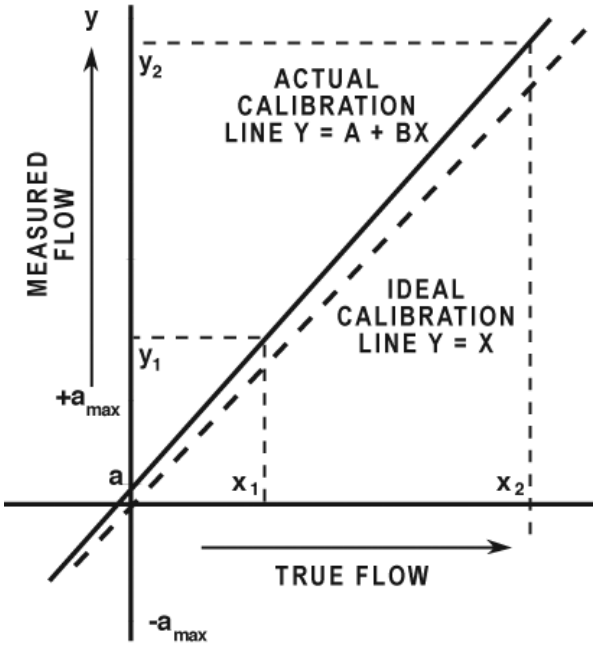


Fig. 6: Absolute accuracy graph showing discrepancy between ideal calibration line and small deviations in slope and offset that result in the actual calibration line.

By David MacGibbon, DVM, 5-92

Summary of Unique Features of Transit-Time Ultrasound Flow Measurement Technology

TRANSIT-TIME ULTRASOUND TECHNOLOGY

- Full-flow illumination
- Dual-crystal reflective or quadruple ultrasonic pathway
- Alternating upstream-downstream pulse-catch mode of operation
- Validated Flow Values - in vitro & in vivo

SYSTEM SOPHISTICATION

- Precalibrated Flowsensors
- Fully automated system. The Meter identifies the Probe size and calibration factor, & adjusts the Meter's flow ranges and gain automatically
- Built-in diagnostic circuitry and display identifies malfunctioning Flowsensors
- Validated Flow Values - in vitro & in vivo

DIFFERENCES FROM ELECTROMAGNETIC TECHNOLOGY

- Excellent zero stability – no need to occlude (clamp) vessel or graft to get true zero
- No electrical interference from other apparatus or from ambient electrical noise
- Directly measures volume rate of flow. Does not derive volume flow from separate estimates of average velocity across a chord or inside vessel cross-sectional area. Does not assume rotational symmetry of flow profile
- No tight fit needed for electrogenesis; therefore is not subject to artifacts in flow sensitivity when Probe motion disrupts uniform electrical contact
- Nonconstrictive Perivascular Probe construction – minimizes risk of vessel spasm
- No electrical contact needed with vessel, tube or flowing liquid
- Insensitive to Hematocrit – measures flow in all fluids; is not dependent upon presence of electrically charged molecules
- Measures flow in liquids other than blood
- No heat artifacts: Probe power dissipation ≤ 5.0 mW

DIFFERENCES FROM DOPPLER

- Directly measures volume rate of flow. Does not derive volume flow from separate estimates of average velocity across a chord and inside vessel cross-sectional area
- Directly measures axial component of flow. Does not derive such a measure from off-axis flow component. Insensitive to vessel Probe alignment and flow turbulence
- Measures flow in all fluids; not dependent on particulate matter to measure flow

Volume Flow - Equipment

This section presents the equipment components required for flow measurement.

T400-Series Consoles & Modules for Research

Transonic's T402 & T403 Consoles allow mix & match Module capability in a single bench-top unit. The TS420 Perivascular Flow Module operates Flowprobes for in vivo blood flow measurements. The Flowprobes are configured for either acute/anesthetized or chronic/conscious protocols and are available for arteries, veins or ducts from 0.25 mm to 36 mm diameter. Inline and Clamp-on style Flowsensors are used on the TS410 Tubing Flow Module for volume flow measurements in tubing. The SP430 Pressure Amplifier Module adds two channels of pressure using Scisense Pressure Catheters (or Traspac fluid-filled catheters). All modules output analog signals in the range of ± 5 volts ready for data acquisition.

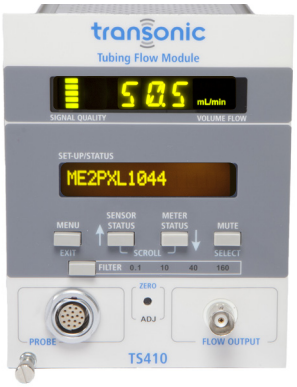
T403 Console with TS410 Tubing Flow Module and TS420 Perivascular Flow Module and SP430 Pressure Amp Module.

Transonic Gold Standard Flow Modules:

- Validated transit-time ultrasound technology
- Direct volumetric blood flow measurement
- High resolution and zero baseline stability
- Continuous beat-to-beat flow data
- Non-constrictive Perivascular Flowprobes for vessels as small as 250 micrometers
- Inline extracorporeal Flowsensors for low flow isolated heart studies
- Solid-state Pressure Catheters for mice, rats and large animals

SP430 is part of the T400-Series system and must be installed in a T402 or T403 console to function.

TS420 Perivascular Flow Module measures volume flow in arteries, veins or ducts in laboratory animals.



TS410 Tubing Flow Module measures volume flow of liquids in flexible plastic tubing.

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Analog Signals and Analog/Digital Interface

ANALOG SIGNALS AVAILABLE ON TRANSONIC FLOW MODULES

Transonic Flow Modules provide the following analog signals on the rear panel of the T400 console.

VOLUME FLOW

Both average (0.1 Hz) and pulsatile (filtered at 10 Hz, 40 Hz, or 160 Hz) flow signals are provided. For some chronic studies, average flow values may be adequate, but in many cases researchers will want to collect the full pulsatile flow signal for beat-to-beat calculations such as stroke volume, vascular resistance etc. This signal has a voltage range of -5 V to +5 V, scaled to match a Flowprobe's flow range. To calibrate or scale the voltage output properly in the data acquisition recording, see 400-Series Operator's Manual for specific details. See below for guidelines to selecting the optimal frequency filter and sample rate.

RECEIVED SIGNAL AMPLITUDE

These signals represent the strength of the ultrasonic beam passing through the Flowprobe and are useful in testing the quality or functionality of a Probe. Low signal strength may indicate an ultrasonic obstruction (such as an air bubble) or a failing Probe and may affect the measurement quality with increases in noise or zero offset. For quality tracking, a very low sampling rate should be adequate. A 2 KHz sampling rate is recommended for bubble detection. There are 2 signal outputs: 1 per transducer pair for 4 transducer Probes. These two signals are identical to each other for 2 transducer Probes. These signals are "normalized" or standardized for the applied Probe use under its factory calibration conditions (see Probe data sheet). The signal ranges from 0 V to +5 V (2 V = 100% factory-calibration signal strength).

PHASE SIGNAL (ULTRASOUND DILUTION)

These signals represent changes in the acoustic velocity of the fluid and are used for ultrasound indicator dilution studies. Transonic Hemodialysis Monitors use a 16 Hz per channel sampling rate for human indicator dilution measurements (1 Hz beat frequency). For smaller animal models, the sampling rate may be scaled up proportionally to the higher heart beat rate. There are 4 signal outputs; 2 per transducer pair (1 offset for reference) for 4 transducer Probes. Two-transducer Probes provide 2 identical signal output pairs.

HEART RATE OR APPLICATION FREQUENCY	LOW PASS FILTER SETTING	RECOMMENDED MINIMUM DIGITAL SAMPLE RATE
Average Flow Recording	0.1 Hz	0.3 Hz
Pulsatile to 60 beats/minute	10 Hz	30 Hz
Pulsatile to 240 beats/minute	40 Hz	120 Hz
Pulsatile to 960 beats/minute	160 Hz	500 Hz

Analog Signals and Analog/Digital Interface Cont.

DIGITAL DATA COLLECTION

A computer record of a study typically combines signals from multiple instruments such as flow, pressure, temperature and other physiological data. This requires a separate Analog-to-Digital (A/D) converter and computer software. Both the software and A/D interface must be matched to the user's study requirements. These computer interface components are not included in the Transonic T400 Flowmeter system, but are available from companies specializing in data collection software. The following notes provide guidance to select software to meet the requirements of Transonic T400 Flowmeter Modules.

ANALOG-TO-DIGITAL (A/D) CONVERTER AND COMPUTER SOFTWARE SELECTION

The operation of an A/D converter is configured by the same computer software that records and analyzes the physiological data delivered by the A/D converter. It is therefore recommended to purchase A/D converter and software from the same vendor to ensure compatibility.

The Data Acquisition and Analysis software packages offered by these companies fall into three categories. Researchers should select a package with features that best meet their requirements.

GLP COMPLIANT SYSTEMS

More demanding data collection for applications such as preclinical drug trials are commonly performed with software that meets GLP ("Good Lab Practices") standards defined for research and products regulated by the FDA. These sophisticated systems have extensive security, validated record keeping and data integrity, and automated analyzers for common research parameters.

MID-LEVEL LIFE SCIENCE SOLUTIONS

These mid range cost systems include companies that specialize in software used in academic institutions with analysis for the common research applications.

ENGINEERING-STYLE PACKAGES

These are less costly solutions without specialized life science analyzers.

Frequency Response for Research Flowmeters

The frequency response and phase delay of Transonic's Flowmeters are a function of the sampling frequency, signal frequency and filter cutoff frequency.

The sampling rate of Transonic Flowprobes ranges from 3.6 KHz (3600 samples/second) in the smallest Probes to 225 Hz (225 samples/second) of the largest Probe sizes. These sample rates allow Transonic Flowmeters to fully resolve pulsatile flow.

The voltage signal output of Transonic Flowmeters is filtered to exclude high frequency noise in the measurement that may be generated from the circuitry and is not flow related. As a general rule, the harmonic content of a pulsatile signal such as heart rate is well described by the first 10 harmonics of the signal. Therefore, a 10 Hz filter should be used for or a 1 Hz heart beat (60 beats/min) to characterize the components of the pulsatile flow signal. For the highest quality measurement, the filter band width chosen should correspond to the frequency cycle of the measurement. The 400-Series Flowmeters have a 160 Hz filter to fully resolve flow at higher frequencies as required in conscious mouse studies where heart rates can reach 750 beats per minute.

The impedance of a blood vessel is calculated by measuring pressure and flow volume and dividing the pressure by the flow volume. This calculation implies that the measurements are performed simultaneously. Yet different instruments may have different delays on the output signal which can add error to the measurement.

The largest component of the time delay in Transonic research Flowmeters is the result of the low-pass 3rd order Butterworth output filter. The table below gives the delay in the output signal for the various research Flowmeters at each filter setting.

FLOWMETER MODEL	FILTER FREQUENCY (MSEC)				
	10HZ	30HZ	40HZ	100HZ	160HZ
T420/T410	23.9		6.8		2.75
Frequency response and phase delay graphs are available for the various filters.					

FILTER SETTING	APPLICATION
0.1 Hz	Average
10 Hz	Heart rate to 60 BPM
40 Hz	Heart rate to 240 BPM
160 Hz	Heart rate to 960 BPM

Transit-time Volume Flowprobes

With over 35 years of experience in perivascular flow measurements, Transonic has a Flowprobe suitable for every blood vessel that is large enough to be isolated. All perivascular Flowprobes are compatible with the TS420 flow module. The sizes range from 0.5 mm to 36 mm and these probes are sized for a non-constrictive fix on the vessel. There are 5 different series of perivascular research probes available to animal research, according to acute/chronic use and species.

PS-SERIES INCLUDING NANOPROBES

0.5-1.5 mm Nanoprobes are scaled to fit mouse anatomy for acute or chronic use.

2-20 mm Flowprobes offer the greatest diversity of customizable features for the perfect fit in any application.

PS- Nanoprobes

PS-Series

PR-SERIES

1 & 1.5 mm Flowprobes for small acute or chronic applications where a more robust design than the Nanoprobes is needed.

PR-Series

PAU-SERIES

8-36 mm COnfidence Flowprobes® with acute or chronic Ultrafit Liners for ascending aorta and pulmonary artery cardiac output studies.

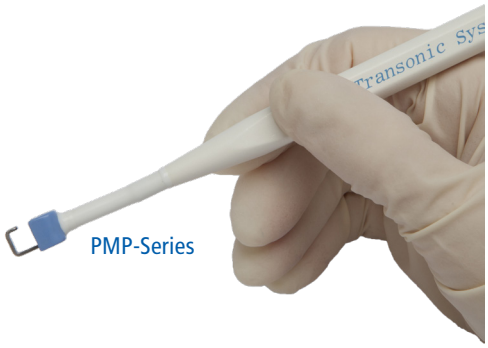
AcuteLiner

PAU-Series

Chronic Liners

PMP-SERIES

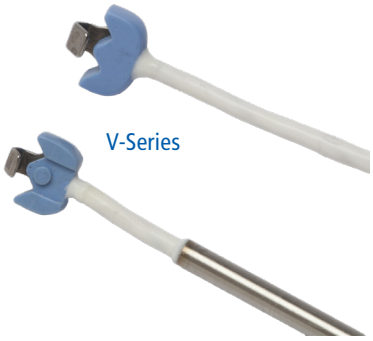
2-14 mm Handle Flowprobes for intraoperative measurements in preclinical animal trials where devices that match those used in clinical settings are preferred.



PMP-Series

V-SERIES

0.5 & 0.7 mm Microcirculation Flowprobes for acute use only. Larger body and more robust than Nanoprobes. Requires more acoustic gel for larger lumen.



V-Series

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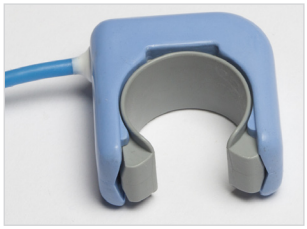
PAU-Series COnfidence Flowprobes® and Ultrafit Liners

Transonic COnfidence Flowprobes® with Ultrafit Liners are designed for easy application and fast signal acquisition on the ascending aorta and pulmonary artery in large animal species. These Flowprobes are designed and calibrated for use with the liners, requiring minimal or no coupling gel for acute use and are ultra-safe for long-term chronic instrumentation.

The COnfidence Flowprobe® consists of a reusable transducer shell and disposable plastic liners that fit around the vessel. The Flowprobes are available in incremental sizes: 4 mm, 6 mm, 8 mm, 10 mm, 12 mm, 14 mm, 16 mm, 20 mm, 24 mm, 28 mm, 32 mm and 36 mm. Ultrafit Liners are supplied in a full-circle configuration for chronic implantation and with one open side for protocols that require only momentary placement. The lumen of Ultrafit Liners for Probes 4 mm to 16 mm matches the Flowprobe size. Larger size Probes (20 mm to 36 mm) are supplied with 2 liner sizes for a quick fit on the vessel without a lot of gel.

Liner for Acute Use

Ultrafit Liners are made of a special plastic that is acoustically transparent to the ultrasound signal that Transonic Flowprobes use to measure blood flow. The liner fills in the space between the vessel and the transducers to transmit the ultrasound. The Ultrafit Liner should be sized to fit the vessel diameter to within 2 mm. A thin smear of Surgilube gel on the Flowprobe shell and inside of the Ultrafit Liner will provide effective contact to immediately receive and maintain a signal during an acute experiment.

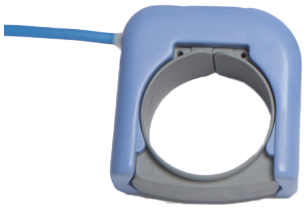


COnfidence Flowprobe® with acute Ultrafit liner.

Use of the full-circle liner is suggested for extended acute protocols as the liner will keep the vessel most securely in place. The full-circle liner can be inserted into the Flowprobe shell in either direction (liner opening against the inside of the Probe or facing toward the opening). The liner opening edge is keyed so that the edges should not overlap. Open-ended liners are for acute use only. This configuration is suggested for short experiments. The installation is quicker since the liner does not have to pass under and around the vessel, but care should be taken to make sure the vessel is completely within the liner lumen. The Flowprobe shell has retaining detents on either side of the shell to lock the liner in place.

Liner for Chronic Use

The Ultrafit Liner is an inert plastic that may be implanted long-term without degradation. The smooth, soft edges of the liner keep the hard Flowprobe shell surface edges away from the vessel and protect it from abrasion and potential rupture. Since there are no air pockets to fill with gel, the COnfidence Flowprobe® with an Ultrafit Liner generates a flow signal immediately following surgical implantation. Experimental flow measurement can proceed and data can be collected without waiting for fibrotic tissue to grow into the Probe for acoustic coupling. Probe sizes 32 mm and 36 mm do not have chronic liners and may require modification for chronic use.



COnfidence Flowprobe® with chronic Ultrafit liner.

Ultrafit Liners are intended for single use. The COnfidence Flowprobe® and Ultrafit Liners can be sterilized by ethylene oxide gas. Re-use of the liner in chronic application is not advised. Additional liners are available from Transonic at a minimal cost.

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Volume Flow - Equipment Use

This section provides the steps for proper equipment use and care in the lab, including set-up, calibration, cleaning, and sterilization, and how specific methodological factors can affect the flow signal.

400-Series Quick Start Guide – Initial Setup

This is only a basic guide. Please refer to the user manual for complete operational instructions.

Transonic's 400-Series Modular Instrumentation Consoles present researchers with the opportunity to configure their Flowmeter set-up to meet their specific application needs. The user can opt at purchase to have one, two or three channels of volume flow, choice between in vivo vascular flow measurement capability or flow measurement in extracorporeal tubing models, and can add a two channel pressure module to simultaneously measure flow and pressure. Each module has features that are specific to the type of measurement to therefore optimize its use and the data it will acquire. The following Reference Guide will walk you through the highlights of each module type (though you may not have each of these installed in your configuration).

Fig. 1: Front of a 400-series console (T403) with TS410 Tubing Flowmeter Module, TS420 Perivascular Flowmeter Module, SP430 Pressure Module (L to R).

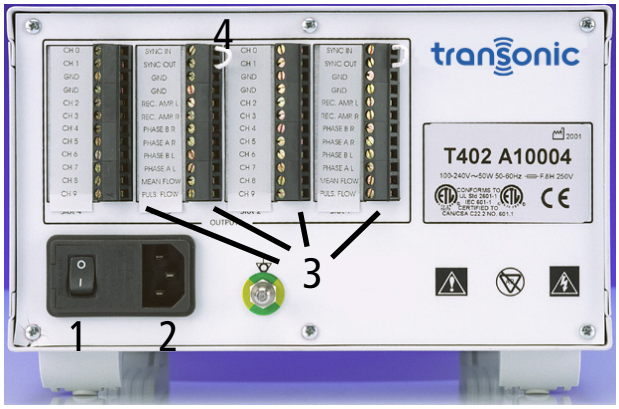

Fig. 2: 400-Series Console (T402) rear panel with power switch (1), line power access (2), secondary signal outputs (3) and synchronization access (4).

Set up the Flowmeter on a table, equipment bench or cart and identify the module capabilities that you have. The 400-series Console Hardware and Data Acquisition System/Computer should be positioned within 1 to 1.5 meters of your surgical area to ensure adequate cable length to reach your experimental set-up. Note: Extension cables of various lengths are available and recommended so that your surgical area is not cramped or cluttered.

Plug in Line Power Cable (2) and turn on console (1). Proceed to the module type that is installed in your console for specific operational instructions.

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TS420 Perivascular Flow Module Quick Start Guide – Initial Setup

TS420 Perivascular Flow Module Operational Features

1. Flowprobe Connection
1A. Calibration Key Port
2. Analog out to DAQ (BNC Cables)
3. Signal Quality of Flowprobe
4. Digital Display of Volume Flow in mL/min or L/min
5. MODE Selection: MEASURE, TEST, ZERO, SCALE
6. Filter Setting: 160 Hz, 40 Hz, 10 Hz, 0.1 Hz
7. Low Flow Range Setting
8. Invert Flow Polarity Setting
9. Needle Meter corresponds to scale voltage
10. Zero Adjust Setting

SET-UP

1. Connect Flowprobe or Flowprobe Extension Cable to Probe input # 1.
   Note: Nanoprobes require use of an extension cable for adequate signal quality.
   Note: If using chronic 4-pin probes, plug Flowprobe specific eprom key in port 1A.
2. Connect BNC cable to BNC output connection # 2. Connect the other end of this cable to your chosen DAQ Input Channel for FLOW.

Complete steps 1 & 2 for all installed modules (TS420; TS410; SP430)

3. Using power switch on rear of the 400-series console, turn on the system and verify that green lights are illuminated in the modules present in the console.

With steps 1, 2 and 3 completed, you can now establish a "Template File" in your chosen software platform. Template files – also known as "settings files" – are software files that have specific calibration data saved for output channels provided by the 400-series.

NOTE: Settings Files for Flow measurements have Flowprobe size specific scaling, so it is important to ensure that the DAQ calibration template is scaled for the correct size Flowprobe if you are using different sizes or change to the "Low Flow" scale during experiment.

TS420 Quick Start Guide – Daily Use Checklist

Note: If equipment is not yet connected, reference "400-Series Quick Start Guide – Initial Setup" on page 16.

1. Turn on Equipment

- Turn on the 400-Series console by switching the power button on the back panel.
- Start the Data Acquisition System (DAQ), load your software program, and select your pre-saved template file.

2. Test the signal quality of the probe

- Connect probe to TS420 meter in TEST mode (# 5).
- Immerse the probe in soft plastic beaker with degassed water or saline and move back and forth to remove small air bubbles that block signals.
- Observe Flow Module's front panel signal quality indicator (# 3) and Digital Display (# 4). The "No Sig" message will be replaced with "Good Sig" as good acoustic conduction is established with the Probe.
- The Signal Quality Indicator should be fully illuminated - all 5 bars will be lighted.
  NOTE: If the Flowprobe has less than 3 bars lit during the water/ saline test (without interruption from bubbles) do not use the Flowprobe for measurements. Contact a Transonic Representative.

3. Select the Filter Setting (# 6)

Low pass filters permit selection of the best frequency response to record accurate waveforms. The filter should be set to 40 Hz for the heart rates in large animal models.

4. Establish the Flowprobe Scale

The flow range of each Flowprobe is scaled according to Probe size. Best practices recommends that you record a two point calibration cycle at the beginning of each recording to confirm the scale settings of the DAQ file against the Flowmeter setting.

- Select ZERO Mode (# 5) to output 0 volts.
- Select SCALE Mode (# 5) to output 1 volt. The digital display (# 4) will indicate the value of the 1 volt scale for the Flowprobe. This value must match your DAQ scale.

Under normal physiological conditions for a given vessel size, mean blood flow values are generally near or below the 1 volt normal scale value for the appropriate Probe size for the vessel. The Low flow setting (# 7) is 1/4 of the normal range to amplify exceptionally low flow signals and provide a four-fold increase in sensitivity.

NOTE: Engaging the Low Flow setting will change the Scale setting and must be also changed in your DAQ recording or recorded values will be erroneous.

NOTE: Peak flows exceeding 5 x scale (5 volts) will be clipped or flattened. You must choose the scale setting (normal or low) that will capture a complete pulsatile waveform even if the average flows are lower.

TS420 Quick Start Guide – Daily Use Checklist Cont.

5. Adjust Zero Offset (when present)

Adjust any zero offset by pushing the recessed ZERO ADJ button (# 10) using a blunt stylus. Best practice would be to zero the Flowprobe on the vessel with flow stopped or occluded. If zeroing the probe in a container, be sure the condition is stable. Note: Reflections on glass containers can cause drift.

6. Begin Measurements

- Put the Flowmeter in MEA Mode (# 5) and place the probe around the vessel of interest ensuring that there is good acoustic coupling (all 5 signal bars should light up).

Note: Air will block the ultrasound signal. Acoustic gel or warm saline can be used to ensure good coupling. The best practice is to use SurgiLube Gel as it is an acoustic match for blood. For more details on acoustic coupling, please see “Keys to Accurate Perivascular Flow Measurements with Transit-Time Ultrasound” on page 22.

- Transonic Flowprobes are bidirectional and may be applied to the vessel in the best direction dictated by the anatomy. If measured flow is negative; reverse polarity of the probe by engaging the Invert button (# 8).

7. Start Collecting Data

After confirming scale settings above, begin recording. Cycle through the 2-point reference calibration signals and start collecting data.

Cleaning & Sterilization of Transonic Flowprobes

Device	All Transonic Reusable Research Perivascular Flowprobes
Warnings	Flowprobes are delicate precision instruments and should be handled carefully at all times. It is critical that the Probe connector be completely dry before use. Air dry or carefully wipe with disposable cloth/paper.
Limitations and restrictions on reprocessing	Connectors for acute use are not sealed and should not be soaked. Connectors for chronic use may be momentarily immersed, then rinsed to remove debris prior to sterilization. Repeated processing has minimal effect on instruments. End of life is normally determined by wear and damage due to use. **NOTE:** Care must be taken when scrubbing the softer materials near the probe head to prevent damage to the silicone.
Preparations at the point of use	Remove excess debris with disposable cloth/paper. Wipe and/or rinse with water to remove excess bio-materials.
Containment and transportation	No particular requirements. **NOTE:** It is recommended that instruments are processed as soon as is reasonably practical following use. Dried-on materials are more difficult to remove.
Cleaning preparations	Flowprobes with sliding cover should be disassembled for a thorough cleaning.
Cleaning solutions	Alkaline, Neutral or Enzymatic. Use only those cleaning agents approved by your governing regulatory agency. Use all cleaning agents according to the manufacturer's directions.
Manual cleaning	**[1]** Rinse excess soil from instrument (temp <30°C, 86°F). **[2]** Using detergent (e.g. Steris Prolystica 2X concentrate Neutral Detergent) and soft brush remove any visible foreign material on all probe and handle surfaces for 3 to 5 minutes. Soaking or immersion in detergent during brushing is allowed. **NOTE:** Excess or aggressive scrubbing of the probe neck can damage the silicone, particularly where it is sealed to the handle. **NOTE:** Connector surfaces may be wiped clean with solutions, but take care not to damage connector pins. If solution gets on pins, carefully wipe them dry as soon as possible. **[3]** Rinse with tap water. **[4]** Visually inspect for cleanliness and repeat cleaning if necessary.
Automatic cleaning	Only use cleaning solutions which have been approved for use with an automatic washer (e.g. Steris Prolystica 2X Concentrate Alkaline Detergent). **[1]** Detergent wash minimum of 2 minutes in hot tap water **[2]** Rinse minimum of 2 minutes at 70°C **[3]** Dry minimum of 15 minutes at 80 °C **[4]** Visually inspect for cleanliness and repeat cleaning if necessary. **NOTE:** Do not exceed 90°C unless the device has the autoclave label on the connector.
Disinfection	After cleaning, all Probes must be sterilized. Additional disinfection is not required and may ultimately damage the Probe. Use only those disinfecting solutions approved by your governing regulatory agency. When disinfection is performed, follow the manufacturer's instructions applicable to the disinfection solution.
Packaging for sterilization	A polyethylene/tyvek pouch sized per the table above may be used provided it is approved by the appropriate regulatory agency for use with the desired sterilization method. Ensure that the pack is large enough to contain the instrument without stressing the seals. Use a pouch that is validated for the specified sterilization cycle. Use approved sterilization wrap to cover instrument tray for Sterrad sterilization according to manufacturer's instructions.

Cleaning & Sterilization of Transonic Flowprobes

<table>
<tr><td rowspan="2">Sterilization</td><td>STERRAD

STERRAD 100
STERRAD 100s: Short cycle
STERRAD 100NX: Standard cycle
STERRAD NX: Standard cycle
STERRAD 200: Short cycle

Follow the instructions for use provided with the STERRAD machine for proper sterilization processing.</td><td>Ethylene Oxide (ETO)

PRECONDITIONING
Humidity: 55-75% RH
Temp: 38-50°C (100-122°F)
Time: 12 hours

EXPOSURE (600±50 mg/L, 3 hours)
Vacuum: 0.8 ± 0.5 "HgA
Sterilant gas: 100% EO
Humidity: 2.4 ± 0.5 "HgA
Temp: 49-54°C (120-130°F)
Time: 3-3.5 hours

POST EXPOSURE
Vacuum: 1.0 ± 0.5 "HgA

AERATION
Temp: 43-55°C (109-131°F)
Time: 12 hours</td></tr>
<tr><td>STERIS

V-PRO MAX
Non-lumen, cycle time = 28 min
Lumen, cycle time = 60 min

V-PRO 1 PLUS
Non-lumen, cycle time = 28 min
Lumen, cycle time = 60 min

V-PRO 60
Non-lumen, cycle time = 28 min
Lumen, cycle time = 60 min</td><td>STEAM (AUTOCLAVE)
Not available for PXN, PXL, PS, PR or PAU series
Only reusable Flowprobes with this symbol on the connector can be autoclaved.
 

GRAVITY DISPLACEMENT STEAM STERILIZATION:
132°C for 15 minutes with 30 minutes dry time
135°C for 10 minutes with 30 minutes dry time

DYNAMIC AIR REMOVAL STEAM STERILIZATION:
132°C for 4 minutes with 20 minutes dry time
134°C for 3 minutes with 20 minutes dry time</td></tr>
<tr><td>Inspection, maintenance and testing</td><td colspan="2">Inspect each Perivascular Probe for:
• A bent reflector (the reflector should be at a right angle to the Probe body).
• Cracks or chips in the plastic Probe body.
• Nicks in the Probe cable (if nicks are observed, do not reuse).
• Damage to the silicone seal (if integrity of the silicone is compromised, do not reuse).
Consult the Flowmeter's Operator's Manual for testing instructions.</td></tr>
<tr><td>Storage</td><td colspan="2">The probe is ready for use after sterilization is complete. There are no additional storage requirements.</td></tr>
</table>

The instructions provided above have been validated by the manufacturer for preparing a device for re-use. It remains the responsibility of the reprocessor to ensure that the reprocessing as actually performed using equipment, materials and personnel in the reprocessing facility to achieve the desired result. Your reprocessing procedure should comply with local regulations.

Keys to Accurate Perivascular Flow Measurements with Transit-Time Ultrasound

Importance of Acoustic Coupling for Accuracy

Highest accuracy with transit-time ultrasound Flowprobes is achieved when the ultrasound signal is transmitted under uniform acoustic conditions. This occurs when the acoustic properties of the coupling media and tissue are stable and most closely match the acoustic properties of the liquid being measured. Since volume flow measurement with Transonic Flowprobes is derived from a phase shift (the difference in upstream and downstream transit-times) and is impacted by changes in the acoustical velocity of the ultrasonic beam, discrete sources of error from acoustical mismatch can be eliminated by observing the following guidelines.

Fig. 1: Upper graphic shows a Perivascular Flowprobe without acoustic couplant. Bottom graphic shows the same Flowprobe with acoustic couplant filling the spaces between the Probe and the vessel.

AIR

Air attenuates the Probe's ultrasound signal and effectively blocks ultrasound transmission. With large air pockets in the path of the ultrasound beam, the Flowprobe receives little or no transmitted signal and accurate flow measurements are not possible. Even small air bubbles can compromise measurement accuracy. Therefore, all spaces between the vessel and Probe must be filled with a suitable coupling agent (Fig. 1).

COUPLANT

The best acoustic couplant is Surgilube (E Fougera & Co.) because it matches the acoustic properties of blood. Media with lower acoustical velocity and impedance than blood are poor coupling agents for blood flow measurement with current transit-time ultrasound Flowprobes. These agents include saline, water, and NALCO 1181 mixed with saline. Aquasonic 100, an acoustic coupling agent used for sonography proved to be only on the borderline of acceptability for use with transit-time Probes. Acoustically mismatched media cause reflections of the ultrasound at the vessel boundary, can substantially change the acoustical beam direction within the Probe, and impose uneven changes in the transit-time ultrasound. Measurements may be unstable, noisy and unpredictable in both positive and negative directions.

FAT

Fatty tissue also has a low acoustic velocity and affects the ultrasonic beam similarly. A pad of fat on the vessel wall in the acoustic pathway of the ultrasonic beam can act like a lens, reflecting or defocusing the ultrasound and altering the transit-time.

TEMPERATURE

Temperature also effects the velocity of ultrasound and should be controlled for the most accurate measurements. Acoustical velocity increases with temperature increase. Transitions of the ultrasound beam from room temperature coupling agent to body temperature vessel wall and blood will alter the transit-time and may exacerbate errors from other sources.

Keys to Accurate Perivascular Flow Measurements Cont.

CHOICE OF A PERIVASCULAR PROBE

Although Transonic Flowprobes are designed for a non-constrictive fit on the vessel, the vessel/probe fit can significantly influence flow signal accuracy. For acute applications, the vessel must fill at least 75% of the Flowprobe lumen to meet published accuracy specifications. A close or snug fit will result in the least measurement variability. A close fit lessens the amount of acoustic gel needed and minimizes its effect on the measurement.

- Choose a range of Flowprobe sizes to cover variability in vessel diameter between subjects so that the 75% vessel fit rule is followed.
- Certain Flowprobes have been designed with increased sensitivity to minimize the effects of acoustic mismatch. These include V-Series Flowprobes for small vessels (<700 micron diameter). V-Series Probes are larger bodied and may be used instead of Nanoprobes.

SUMMARY

Subtle phase shifts in the ultrasonic beam may be caused by inappropriate acoustic conditions during the experiment and will affect the accuracy of the measurement. Acoustically tested and approved coupling agents should be used with Transonic Flowprobes. Fatty tissue should be carefully cleaned from the vessel where the Probe is placed. Controlling temperature in the acute experiment makes excellent physiological sense, in addition to being good acoustic practice. Transonic Perivascular Flowprobes are calibrated for measurements of blood at 37°C and will give the most accurate readings if used within a ± 2 - 3 degree range. Gels may be warmed on a heating plate and the Probe itself should be allowed to equilibrate to this temperature for about an hour prior to use.

Keys to Stabilizing Flowprobes

Following are several ways to stabilize Probes that can be applied to various applications, acutely or chronically.

PROBE SIZE

Make sure that the size of the Probe is appropriate for the vessel diameter. The vessel should fill 75 -95% of the Probe lumen. If it is an acute application: a closer fit will be more stable because it will use less gel.

CABLE EXIT

The position of the cable (back, side or lateral) is often determined by the anatomical placement of the Probe and the adjacent tissues. Back (perpendicular to the vessel) is more convenient if the approach is deep. Side (parallel to the vessel) is useful if there is access to lay the Probe and cable flat along side the vessel. A suture may be applied around the cable to keep the Probe in place. There are also suture holes in opposite sides of the reflector and slide cover.

SILICONE WRAP

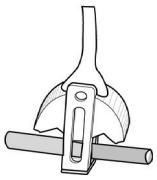
This goes around the Probe and vessel like an envelope and extends the length of the Probe along the vessel to provide more stability. The wrap gives additional places where sutures may be placed for stability. The wrap also helps to keep gel in place. It is typically used on side exit Probes, but may be applied other Probes too. See the Rabbit Renal Artery Surgical Protocol.

SILICONE FLANGE

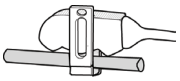
This is a flange around the perimeter of the Probe. It is typically used in LAD coronary artery applications to keep a Probe around a deep vessel from pulling the vessel out of its natural position. Suture holes are provided to sew the Probe down on the tissue for stability. It is also applied in uterine artery applications and has been successful in stabilizing a Flowprobe on the thoracic duct. See Dog LAD Surgical Protocol (RL-1-sp).

ACOUSTIC COUPLING GEL

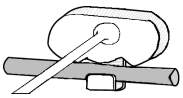
If gel melts out during a long experiment and is the cause of the instability of the signal, the customer should try a closer fitting Probe. The modifications above help to keep the gel in place, but it is also possible to use an angio catheter to deposit more gel in place when it does melt out - or consider using Nalco 1181 super-absorbant powder to make the gel more viscous (this is only suitable for terminal experiments). See Acoustic Couplants section.



Back cable exit perpendicular to vessel.



Side cable exit parallel to vessel.



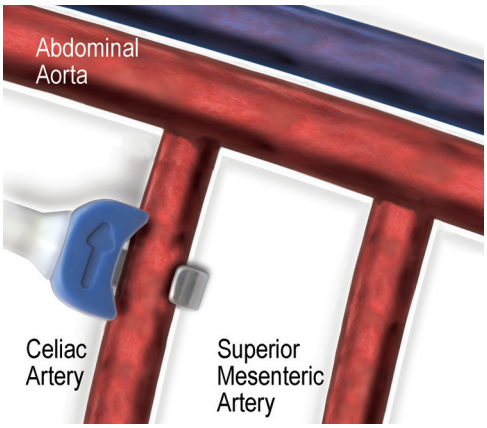
Lateral cable exit for thoracotomy.

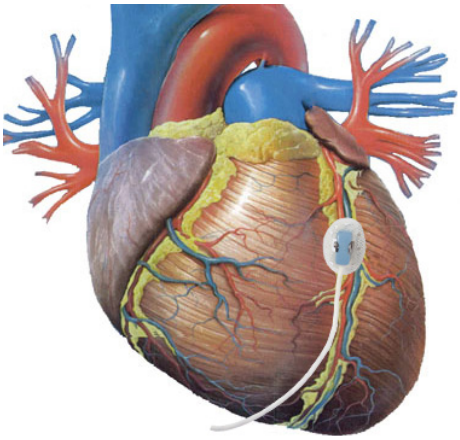
Silicone Wrap

Front view of Silicone Flange on Probe

Back view of Silicone Flange on Probe

Applications and Surgical Protocols





For each application we will provide a summarized surgical protocol and techniques to be the starting point for your own protocol. This includes expected vessel dimension, Flowprobe configurations and data traces when available. For exact vessel diameters, please measure your vessel of interest yourself.

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Aorta or Pulmonary Artery Ultrafit Liners (PAU-Series) Implantation Protocol: Chronic Flow Measurements

Chronic Placement Procedure

Transonic COnfidence Flowprobes® with Ultrafit Liners are designed for easy application and fast signal acquisition on the ascending aorta and pulmonary artery in large animal species.

Ultrafit liners are supplied in a spread position for easy application (Fig. 1). Use, the finger of a latex surgical glove as a "leader" to guide the liner around the vessel. The elasticity and smoothness of surgical glove latex material allows the surgeon to apply controlled pressure on the leading edge while the liner slips between the tissues.

1. Prepare the Liner
   a) Using surgical scissors, trim the corners of the flange to a bevel on both sides of the opening of the liner.
   b) Pass 2 (0 silk recommended) sutures through each suture hole on the ends of the liner (Fig. 2).
   c) Cut the small finger from any size surgical glove (6, 7, 8) and place it over one end of the liner as a "leader" to draw the liner around vessel (Fig. 2).
   d) Tie a suture laterally around the latex "leader" to secure it on the liner (Fig. 3).
2. Isolate a sufficient length of the vessel using blunt dissection to pass the liner around the vessel.
3. Using curved right angle forceps under the vessel, grasp the elastic tubing leader and gently guide the liner around the vessel (Fig. 4). Use the elasticity of the tube to draw the liner and allow the tissues to ease over the larger corners of the liner.
4. Once both ends of the liner are around the vessel, remove the elastic tube and tie one pair of the pre-placed sutures together (Fig. 5) to close the liner taking care that the ends of the liner do not overlap. The liner edge is keyed so that two ends will meet smoothly.
5. Use a smear of SurgiLube gel on the inside of the shell body for immediate acoustic coupling. This also provides lubrication to slide the Probe shell easily over the liner.
6. Place the Probe shell over the open end of the liner and slide it down over the parallel surfaces of the liner. Apply a slight pressure on the top of the Probe shell to pass the liner over the retaining detents and to ensure that the vessel is positioned fully within the Probe.
7. Tie the second pair of sutures over the top of the Flowprobe shell (Fig. 6). The sutures keep the liner from sliding out of position during beating of the heart. This is recommended for both acute and chronic protocols as significant displacement in liner/shell alignment can affect accuracy.
8. Tunnel the Flowprobe cable and close as protocol requires.

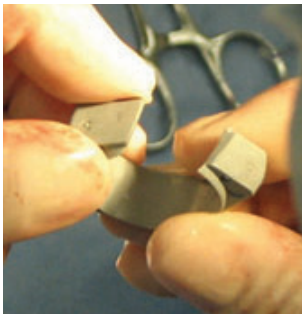

Fig. 1: Ultrafit Liner in spread position.

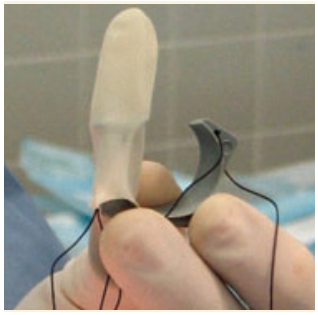

Fig. 2: Latex surgical glove is used to assist in leading the liner around the vessel.

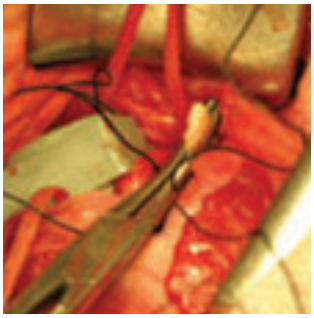

Fig. 3: Positioning the liner around the vessel.

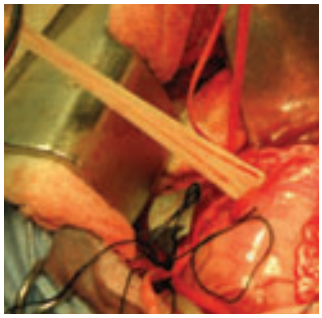

Fig. 4: Forceps grasping the elastic leader to guide the liner around the vessel.

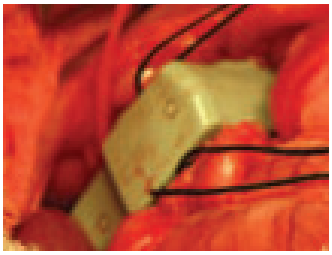

Fig. 5: Tying the pre-placed sutures together to close the liner.

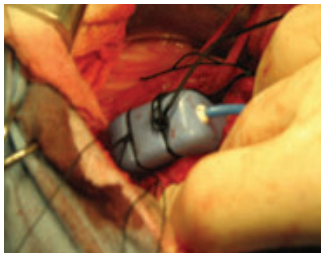

Fig. 6: Flowprobe shell in position over the liner.

ACKNOWLEDGEMENT

Protocol courtesy of J.A. Sala-Mercado CVRI, Wayne State Univ., Detroit, MI and R.L. Hammond, William Beaumont Hospital, Royal Oak, MI,

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Bovine Afferent Mammary Duct: Chronic Lymph Flow Measurement

APPLICATION BASICS

Site:	Afferent Mammary Duct
Species:	Cow
Weight:	450 kg
Duration:	Chronic
Vessel Diameter:	1.5 -2 mm

PROBE

Size:	2 mm (side exit)
Reflector:	L with sliding cover
Connector:	4-pin
Cable Length:	60 cm
Catalog #:	MC-2PSS-LS-WC60-CM4B-GC

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

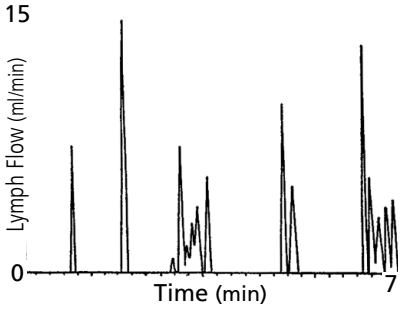

Fig. 1: A trace showing normal lymph flow in the afferent mammary gland lymphatic duct of a lactating cow.

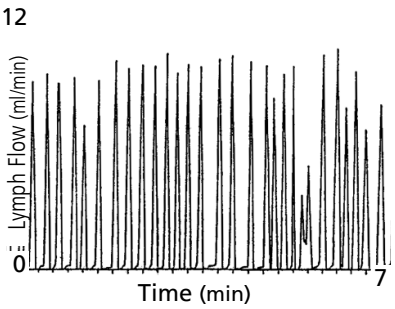

Fig. 2: A trace of abnormal lymph flow in the afferent mammary gland lymphatic duct during inflammation.

Application

This protocol was developed to study changes in flow dynamics and lymph composition during episodes of mastitis. Lymph flow appears to be a dramatic early indicator of infection in mammary gland.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Rotate the cow slightly towards dorsal recumbency. Abduct the left hindlimb to expose the left lateral surface of the udder. Make an incision in the lateral wall of the udder, just dorsal to the teat of the left hind quarter. Continue the incision through the lateral suspensory ligament. Inject blue patent dye into the parenchymal tissue adjacent to the incision. The dye is absorbed by the lymphatic system and will help identify the afferent lymphatic duct. Pretreat a 30 cm long polyethylene cannula (1.5 mm ID, 2.5 mm OD) with heparin, and place it in this vessel.

Place the Flowprobe around the lymphatic duct above the cannulation site. Pass the Probe cable and cannula through a subcutaneous tunnel to an exit site in the right rear corner.

Bovine Afferent Mammary Duct: Chronic Lymph Flow Measurement Cont.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

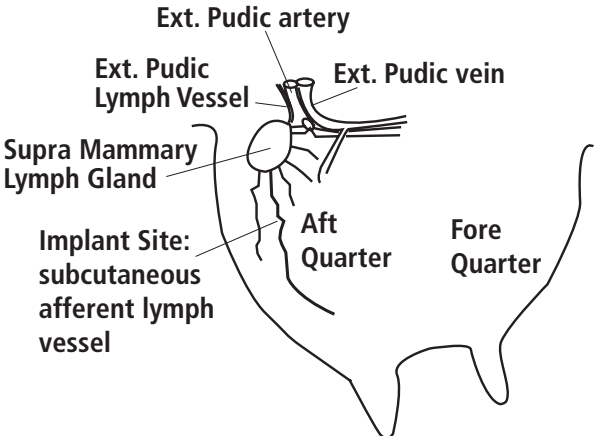

Fig. 3: Schematic of anatomical site.

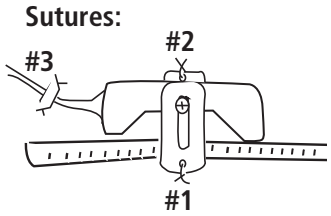

Fig. 4: Flowprobe suture sites.

ACKNOWLEDGEMENT

Dr. R. Gorewit, Dept. of Animal Science, Cornell University, Ithaca, NY 14853

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Gorewit RC, Aromando MC, Bristol DG, "Measuring Bovine Mammary Gland Blood Flow Using a Transit-Time Ultrasonics Flowprobe", J Dairy Science 1989; 72(7).

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Gorewit RC, Scott NR, "Cardiovascular Responses of Cows Given Electrical Current During Milking", Journal of Dairy Science 1986; 69(4): 1122-1127.

Bovine External Pudic Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	External Pudic Artery
Species:	Cow
Weight:	600 kg
Duration:	Chronic
Vessel Diameter:	11 -16 mm

PROBE

Size:	12 - 16 mm (side exit)
Reflector:	U with wide silicone shield
Connector:	10-pin
Cable Length:	1 meter
Catalog #:	MC-12PSS-USW-WC100-CRS10-GC

FLOWMETER

TS420 Perivascular Module

Application

This protocol was used to validate the transit-time technique. It has also been used to study the effect of "stray voltage" on dairy cows. Other possible uses include studies on the hormonal control of lactation, as well as the pathogenesis of udder edema and mastitis.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Make a 10 to 12 cm incision over the inguinal region between the medial thigh and the lateral surface of the mammary gland. Locate the inguinal canal. Carefully isolate the pudendal artery just ventral to the inguinal canal. Place the Flowprobe around the pudendal artery by unscrewing the reflector, fitting the reflector and Probe around the artery and then reattaching the reflector to the Probe body with the screws.

Flow Ranges Observed

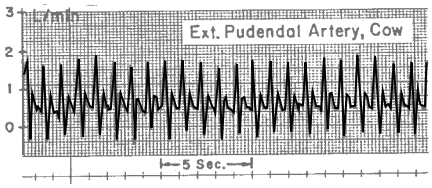

Fig. 1: Normal mean flow is 2.5 L/min. This increases to 3.7 L/min during milking

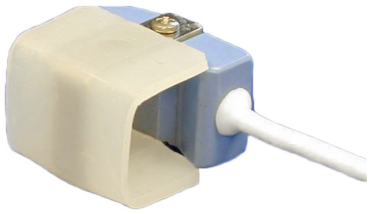

Fig. 2: Flowprobe with wide silicone shield

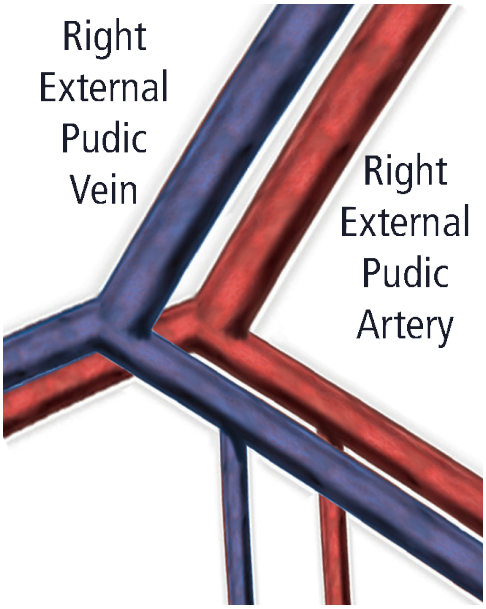

Fig. 3: Purdic vessel schematic

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Bovine External Pudic Artery: Chronic Blood Flow Measurement Cont.

Suture the Probe via the silicone shield, directly into the musculature of the external pudendal artery. Direct suturing is necessary because the vessel is loosely attached and normally follows a sigmoidal path. Correct suturing prevents twisting and constriction of the artery.

Use a 2 cm blunt trochar to create a subcutaneous tunnel to the flank to exteriorize the Flowprobe cable (keep connector capped during implantation, exteriorization and when not connected to the Flowmeter for measurements). Place a mattress suture in the skin around the cable exit site to stabilize the cable and reduce the risk of infection. Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

ACKNOWLEDGEMENT

Dr. R. Gorewit, Dept. of Animal Science, Cornell University, Ithaca, NY 14853

REFERENCES

Gorewit RC, Aromando MC, Bristol DG, "Measuring Bovine Mammary Gland Blood Flow Using a Transit-Time Ultrasonics Flowprobe", J Dairy Science 1989; 72(7).

Gorewit RC, Bristol DG, Aromando MC, Thomas GG, "Mammary Blood Flow of Cows Measured by Ultrasonics and Electromagnetic Flow Meter," J Dairy Science 1984; 67 Sup: 159.

Gorewit RC, Scott NR, "Cardiovascular Responses of Cows Given Electrical Current During Milking", J Dairy Science 1986; 69(4): 1122-1127.

Note: Protocol has been updated to reflect advances in Probe technology.

Cat Renal Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Renal artery
Species:	Cat
Weight:	4 kg
Duration:	Chronic
Vessel Diameter:	1.5 mm
PROBE	
Size:	2 mm (side exit)
Reflector:	L with sliding cover
Connector:	10-pin
Cable Length:	60 cm
Catalog #:	MC-2PSS-LS-WC60-CRS10-GC
FLOWMETER	TS420 Perivascular Module

Flow Ranges Observed

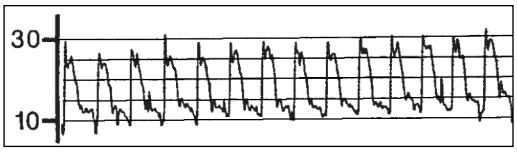

Fig. 1: Day 21: Instantaneous renal blood flow in a 4 kg cat varied in a pulsatile manner from 10 to 30 ml/min.

Application

This protocol was used to validate transit-time flow measurement against microspheres. Renal blood flow also has been used to evaluate potential antihypertensive agents and to study eclampsia. Renal blood flow may also be useful in studies of nephrotoxic antibiotics, diuretics and inotropic agents. A retroperitoneal approach may be simpler when a single Probe is to be implanted.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices. With the cat in dorsal recumbency, make a ventral midline incision from the xiphoid to the umbilicus. For access to the left kidney; lift the descending colon to displace the intestine to the right. For access to the right kidney: lift the descending portion of the duodenum and displace the other loops of intestine to the left.

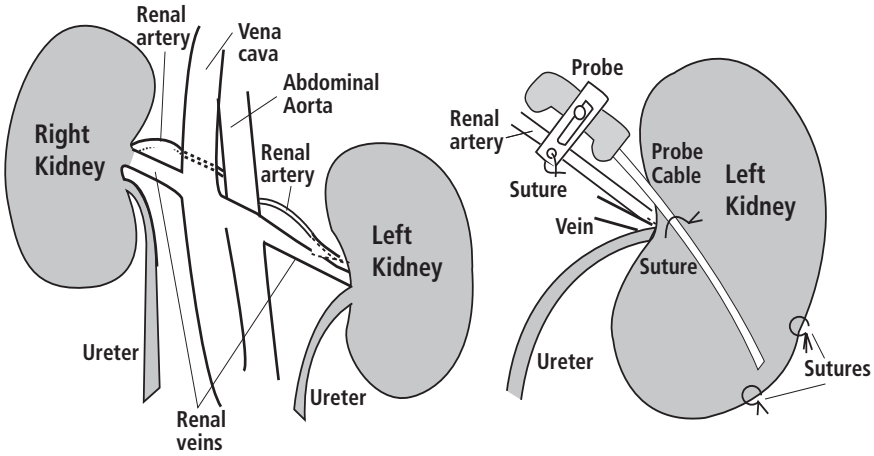

Fig. 2: Anatomical site.

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Cat Renal Artery: Chronic Blood Flow Measurement Cont.

Note that the right kidney is cranial to the left kidney. Cover viscera with moist laparotomy packs.

Deflect the kidney laterally and gently dissect the tissue craniomedial to the hilus of the kidney. Take care not to damage the ureter which exits caudolaterally. Locate the renal vein and place a silk suture around it. Locate the renal artery and place a silk suture around it.

Place a 2PS Probe around the artery (or paired arteries) and close the sliding cover of the reflector. Position the kidney caudally and suture the renal capsule to the body wall. This helps stabilize the renal artery. Suture the cable to the renal capsule and the body wall and make a stab incision lateral to midline. Pass the cable through the stab incision and create a subcutaneous tunnel to bring the cable to a small subcutaneous pouch. Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

When handling chronic instrumentation, cables and connectors can be readily exteriorized at the time of implantation surgery or kept in a subcutaneous pouch until flow data recording is desired. In this protocol, cable and connector were kept in a subcutaneous pouch. Fibrotic tissue effectively seals the tunnel containing the cable within seven days post surgery. Whenever blood flow data is required, the cable and connector can be exteriorized under a light anesthesia procedure.

ACKNOWLEDGEMENT

Dr. Alan Dobson, Dept. of Physiology, NYS College of Veterinary Medicine, Cornell University, Ithaca, NY 14853.

REFERENCE

Rosin E: Nephrectomy. In Current Techniques in Small Animal Surgery, 2nd ed., Edited by M.J. Bojrab., Philadelphia, Lea and Febiger, 1983.

Dog Hepatic Artery & Portal Vein: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Hepatic Artery
Species:	Dog
Weight:	25 kg
Duration:	Chronic
Vessel Diameter:	2.5 mm

PROBE

Size:	3 mm (side exit)
Reflector:	L with sliding cover
Other:	Silicone wrap
Catalog #:	MC-3PSS-LS-WC100-CM4B-GC
FLOWMETER	TS420 Perivascular Module

APPLICATION BASICS

Site:	Portal vein
Species:	Dog
Weight:	25 kg
Duration:	Chronic
Vessel Diameter:	12 mm

PROBE

Size:	12 mm (side exit)
Reflector:	U with Silicone Shield
Cable Length:	1 meter
Catalog #:	MC-12PSS-USW-WC100-CRS10-GC
FLOWMETER	TS420 Perivascular Module

Application

The measurement of portal and hepatic blood flow has an important role in the study of hepatic physiology. One protocol was developed to study the hepatic extraction of metabolic substrates and also included the implantation of vascular occluders on the portal vein and the hepatic artery. Vascular access ports were also implanted in the hepatic vein, the hepatic artery and the portal vein. The concentration of any substrate may be determined from blood samples drawn from the vascular access ports. Since the total metabolic flux is the product of blood flow and the substrate concentration, total hepatic extraction may be determined. The relative contributions of the hepatic and portal vessels can be varied at will with the vascular occluders.

Flow Ranges Observed

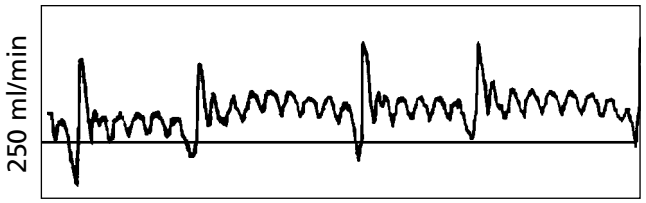

Fig. 1: Instantaneous flow ranged from 200 to 350 ml/min. This pulsatile flow example is from an acute experiment in an anesthetized dog. Note the periodic spikes from respiratory activity. Typical mean flow from chronic experiments ranged from 376 to 450 ml/min.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

With anesthetized dog in dorsal recumbency, make a midline skin incision from the xiphoid cartilage to the umbilicus. Continue the incision through the linea alba and the peritoneum to expose the lobes of the liver. Deflect the lobes of the liver cranially and identify the splanchnic vessels. Carefully dissect free a 2 cm segment of the portal vein and strip all fat from it for proper acoustical coupling.

Slip the large U bracket around the vein, attach the body of the Probe and secure the screws. Rotation of the Probe around the vein may be necessary to align the screwdriver with each screw. Suture the cable to the perivascular connective tissue. Identify the gastroduodenal artery. It is the continuation of the hepatic artery after the last hepatic branch and runs adjacent to the bile duct. Ligate it to isolate the hepatic circulation from that of the stomach and pancreas.

Dog Hepatic Artery & Portal Vein: Chronic Blood Flow Measurement Cont.

Mobilize a 1 cm segment of the hepatic artery and strip away any fat. Pass the L bracket around the hepatic artery, close the slide and secure the screw. Wrap the silicone sheet around the Probe so that the parts of the bracket with the suture holes extend through the cutouts in the silicone sheet. Suture the ends of the silicone sheet as shown in Fig. 3. Place several 4-0 silk sutures between each edge of the silicone wrap and perivascular connective tissue as shown in Fig. 4 Also place a single suture around the cable for strain relief.

Exit the Probe cables through a stab incision high on the abdominal wall. Make a skin incision between the shoulder blades and create a subcutaneous tunnel from the stab incision to the midscapular incision. Pull the cables through the subcutaneous tunnel. Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices .

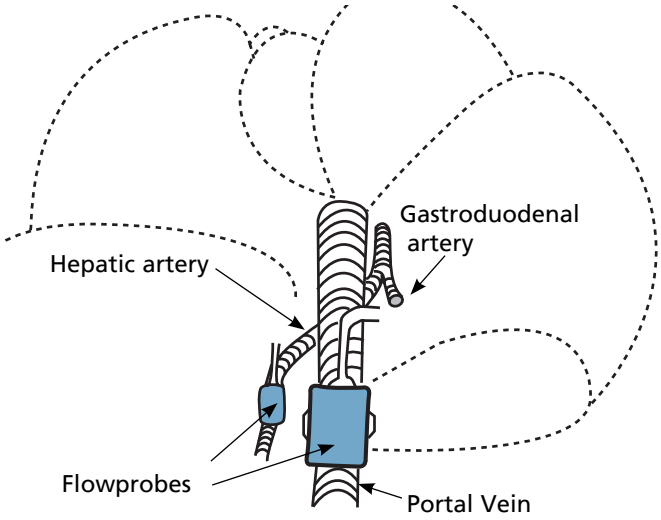

Fig. 2: Flowprobes on hepatic artery & portal vein

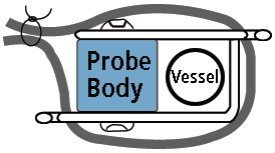

Fig. 3: Silicone Wrap

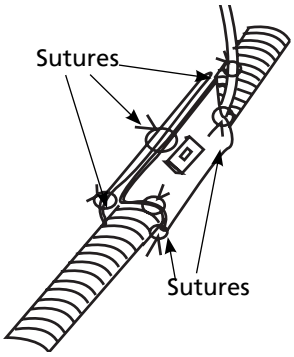

Fig. 4: Suturing

ACKNOWLEDGEMENT

Flow trace: Dr. Ronald Beck, University of South Carolina, School of Medicine, Dept. of Physiology, Columbia, SC 29208. ral Science, Uppsala, Sweden

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Dog Left Anterior Descending (LAD) Coronary Artery: Acute and Chronic Blood Flow Measurement

PERIVASCULAR FLOWPROBE RECOMMENDATIONS FOR LAD						
DURATION	**WEIGHT (KG)**	**PROBE**	**SF-SILICONE FLANGE**	**CABLE LENGTH**	**CONNECTOR**	**CALIBRATION**
Acute	10 - 15	MA-1.5PRB	optional	WC100 1 meter	CRA10	GA acute
	18 - 25	MA-2PSB				
Chronic	8 - 12	MC-1.5PRB	suggested	WC40 40 cm	CM4B	GC chronic
	16 - 25	MC-2PSB			CB12	
	20+	MC-2.5PSS			CB12	

Canine LAD Protocol

The use of Transonic Flowprobes for measurements on canine coronary arteries is a fairly common application, though protocols vary considerably. The following protocol offers suggested techniques for stabilizing the Flowprobe for chronic implant. Some of our customers have found the silicone flange quite helpful in maintaining position of the Flowprobe while allowing the Probe to move in unison with the heart. In other protocols, a section of the pericardium is patched over the Flowprobe to maintain position if the flange would interfere with other instrumentation, or if the Probe is to be used on other vessels where not applicable.

Fig. 1: Dog coronary Flowprobes.

Note: In acute applications any air within the Flowprobe window (between the Flowprobe and the vessel) must be displaced with gel or some other acoustically appropriate medium to transmit the ultrasound. A closer fitting Probe requires less gel and surface tension tends to hold the gel in place longer.

Fig. 2: Flowprobe with SF-silicone flange.

The Probe must be positioned and secured on the cardiac wall so that the paraconal interventricular branch of the left anterior descending (LAD) coronary artery passes through the acoustic window, without rubbing against the bracket. The ultrasonic field of illumination, should be free of fat deposits, and for acute applications, filled with an ultrasonic couplant.

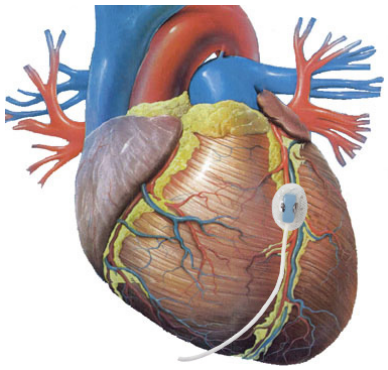

Fig. 3: View of dog heart with Flowprobe implanted on left anterior descending (LAD) coronary artery.

Surgical Approach

1. The Transonic 2PS Probe consists of three pieces: a blue epoxy body, an L or J-shaped metal bracket and a straight metal bracket with a channel running through its center. Prior to surgery, loosen the Phillips head screw securing the straight bracket and slide it out to open the Probe window. The small hole on the end of the bracket will permit you to conveniently open and close the window using the point of the screwdriver. The Transonic 2PS-SF Probe has a silicone flange for easier positioning. In its closed position, the metal brackets are flush with both the bottom of the Probe body, and with each other at the opposite end. For acute application, submerge the Probe head in a beaker of saline prior to use.

Dog Left Anterior Descending (LAD) Coronary Artery: Acute and Chronic Blood Flow Measurement Cont.

2. Perform a left thoracotomy through the 4th intercostal space (between the 4th and 5th rib). The apical and cardiac lobes of the lung are retracted dorsally and caudally, and are held away from the operative site by moist packs to expose the mediastinum above and behind the hilus of the lung. This will expose the operative field.
3. The pericardium is then incised perpendicular to the phrenic nerve by picking it up with smooth thumb forceps, nicking it with a scalpel, and extending the incision with Metzenbaum scissors. The incision is started about 0.5-1 cm ventral to the phrenic nerve and is extended to the apex of the heart. For better exposure, the pericardium may be sewn to the thoracic opening, to form a cradle.
4. The origin of the left coronary artery may not be readily visible because it is usually buried in fat under the atrial appendage. The LAD artery, however, can usually be seen as it emerges from the fat in the atrioventricular sulcus.
5. As gently as possible, bluntly dissect the area of the LAD artery which is to receive the Probe from any surrounding fat over a length of 16 mm to 20 mm. Side branches which interfere with the application of the Probe may be tied off with 3-0 cardiovascular silk suture.
6. Applying the PS Flowprobe (Fig. 4)
    a. Gently slip the L-shaped bracket under the section of the LAD artery; slide the straight bracket to its closed position; tighten the screw.
    b. To position the Probe properly in relation to the LAD artery and the heart wall, place a suture through the hole in the top of the straight bracket and pull the Probe down into the cardiac wall. This will prevent the Probe from pulling the LAD out of position.
    c. Place the next suture through the hole in the L-bracket, below the Probe body, and fasten to the cardiac wall. This suture aligns the axis of the Probe with the artery and as such should only hold the Probe to the cardiac wall, not pull the Probe into it. The L-shaped bracket side of the Probe is now flush with the heart wall.
    d. For an acute experiment, fill the acoustic window not occupied by the LAD with an ultrasonic couplant (e.g., the animal's own blood, held in the window until it coagulates, or an ultrasonic coupling gel).
7. Using the 2S-SF Probe (Fig. 5)
    a. Gently slip the L-shaped bracket under the section of the LAD artery to be monitored, slide the straight bracket to its closed position, then tighten the screw.
    b. Position the Probe, so that the Probe bracket lies in the atrioventricular sulcus, with the LAD artery running through the acoustic window and perpendicular to it. The silicone flange should be flush with the heart wall, with the Probe body visible and facing outward. The silicone flange is then sutured to the heart wall, to ensure that the LAD artery will not be pulled from its course by the Probe.
    c. For a chronic application, use four sutures to secure the silicone flange to the cardiac wall. This will keep the Probe axis aligned with the axis of the LAD artery. For an acute application, use two sutures at one end of the silicone flange, then gently lift the other end and insert an ultrasonic couplant in the balance of the acoustic window, not occupied by the LAD artery. Then place the additional two sutures to hold down the other end of the silicone flange.

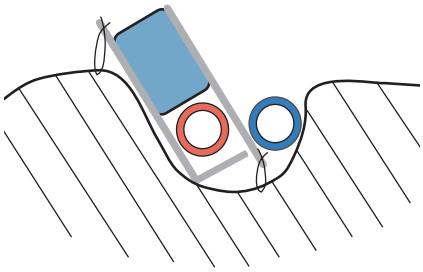

Fig. 4. Cross-sectional view of heart with a Flowprobe installed on lower anterior descending coronary artery.

Dog Left Anterior Descending (LAD) Coronary Artery: Acute and Chronic Blood Flow Measurement Cont.

8. For both the 2S and 2S-SF Probe
   a. Use an additional suture, silk (3-0 or 4-0) to fasten the Probe cable onto the heart (Fig. 6). The suture point on the heart is chosen to maintain the Probe axis parallel to the LAD. Care should be taken not to make the suture overly tight, as it might then cut through the silicone cable jacket. Due to the curvature of the heart, the cable might have to be elevated to maintain the alignment between the LAD artery and the acoustic window. This can be done by crossing a strain relief loop under the Probe's cable exit, or by suturing a piece of surgical sponge under the cable.
   b. For an acute experiment, some adjustment of the Probe position may be necessary to achieve an acceptable signal strength. Observe the Probe's ultrasonic coupling by connecting the Probe to the Flowmeter. In its test mode, the digital panel meter displays the Probe size, plus a rough indication of the ultrasonic signal coupling (e.g.,"Lo" for low, "Gd" for good). The analog display provides a precise measure for the ultrasonic signal strength (e.g. 0.31 = 310 mV received signal). If this signal is more than 30% below the signal strength of the Probe when submerged in saline, the acoustic window has not been properly filled with the couplant, which should be reapplied.
9. For chronic implantations, bring the cable out through a separate stab opening, between the 5th and 6th or 3rd and 4rd ribs. This opening is made more dorsal than the incision site, as the motion between the pectoral muscles and ribs will shorten the lifespan of the Probe cable. From there it is tunneled under the skin to a convenient exit on the back of the animal. Close the operative site, following standard surgical procedure. Allow approximately three to five days for the signal to stabilize.

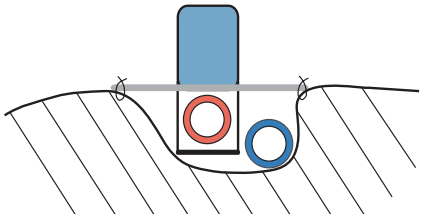

Fig. 5. Cross-sectional view of heart with Flowprobe installed on lower anterior descending (LAD) coronary artery using a silicone flange.

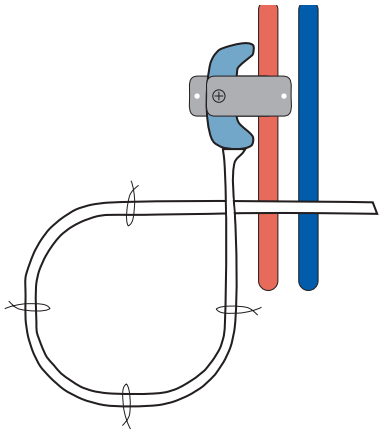

Fig. 6. Strain relief loop elevates Probe and brings it in line with lower left anterior descending (LAD) coronary artery. A surgical sponge may also be used.

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Dog Pancreaticoduodenal Vein: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Pancreaticoduodenal vein
Species:	Dog
Weight:	31 - 39 kg
Duration:	Chronic
Vessel Diameter:	4 mm

PROBE

Size:	4 mm (side exit)
Reflector:	L with sliding cover
Cable Length:	60 cm
Catalog #:	MC-4PSS-LS-WC60-CRAS0-GC

FLOWMETER	TS420 Perivascular Module

Flow Ranges Observed

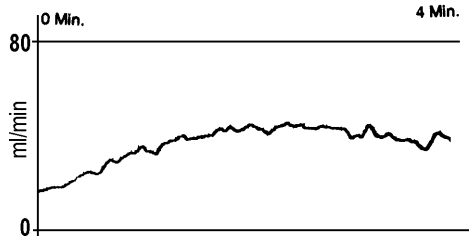

Fig. 1: Mean flow in anesthetized laporotomized dog was 5-15 ml/min In the conscious dog after recovery, basal flow was 5-45 ml/min. This increased to 3 to 5 fold within 1.5 min of feeding.

Application

This protocol was developed to study the neurohumoral regulation of insulin secretion. Blood sampling catheters are also implanted so that the concentration of various neuropeptides and hormones may be determined simultaneously in pancreatic venous and peripheral arterial plasma. Given the A-V concentration gradient, pancreatic blood flow and hemotacrit measurements, a researcher may directly calculate the local output of neurotransmitters and hormones from the duodenal lobe of the pancreas in conscious dogs.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

With anesthetized dog in dorsal recumbency, make a midline skin incision from the xiphoid cartilage to the umbilicus. Continue the incision through the linea alba and the peritoneum to expose the duodenum and associated lobe of the pancreas.

Identify the cranial pancreaticoduodenal vein. It drains the right lobe of the pancreas and merges into the portal vein. Pass the L bracket around the vein, close the slide and secure the screw. Suture the reflector bracket to the fatty tissue around the duodenum. Also place a single suture around the cable for strain relief.

Dog Pancreaticoduodenal Vein: Chronic Blood Flow Measurement Cont.

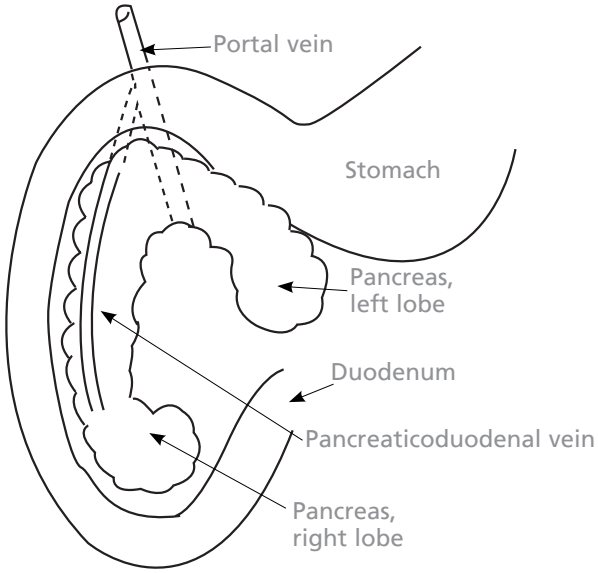

Fig. 2: Schematic of anatomical site

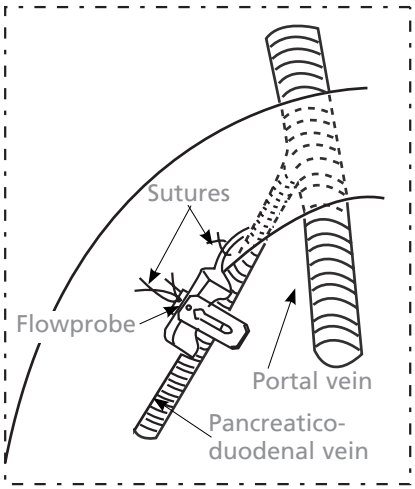

Fig. 3: Schematic of surgical site

Exit the Probe cable through a stab incision just below the last rib. Make a skin incision behind the shoulder between the shoulder blades and create a subcutaneous tunnel from the stab incision to the skin incision. Pull the cable through the subcutaneous tunnel and close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

ACKNOWLEDGEMENT

Dr. Beth Dunning, Diabetes and Metabolism, Sandoz Research Institue, Route 10, East Hanover, NJ 07936

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Rix Kuester, Dept. of Animal Surgery, VA. Medical Center, Seattle WA 98108

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Dog Renal Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Renal Artery
Species:	Dog
Weight:	15 kg
Duration:	Chronic
Vessel Diameter:	2.5 mm

PROBE

Size:	3 mm
Connector:	10-pin
Reflector:	L with sliding cover
Cable Length:	1 meter
Catalog #:	MC-3PSS-LS-WC100-CRS10-GC

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

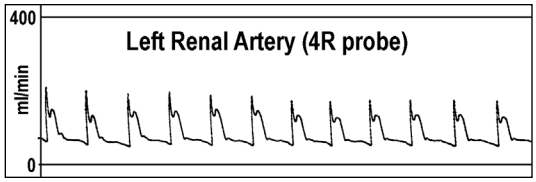

Fig. 1: Left renal artery flow using a 4mm probe

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Dr. Allan Buchholz, Sterling Research Group, 81 Columbia Turnpike, Rensselaer, NY 12144 Vita Lanoce, Squibb Pharmaceuticals, Rt. 206 and Provinceline Rd., Princeton NJ. 08543

Application

The measurement of renal blood flow has an important role in research on hemodynamics, electrolyte regulation and pregnancy induced hypertension. This protocol was used to test potential antihypertensive agents. Other studies have focused on diuretics and nephrotoxic agents. While average renal flow may also be obtained from the renal vein, the pulsatile waveform of the renal artery provides additional information and visual confirmation of a functioning chronic implant.

Variations of this protocol include a ventral approach for situations where access to both kidneys is desired or other protocols require a laparotomy. One experienced researcher sutures the Probe with the cable facing the opposite direction and a loose suture suspending the Probe from the body wall. Another reports fixing the position of the kidney by suturing the renal capsule to the body wall.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices. With anesthetized dog in right lateral recumbency, palpate the left kidney and visualize the location of the renal vessels. Make a 4 cm vertical skin incision over the kidney. Continue the incision by bluntly dissecting through the most superficial muscle layer, the cutaneous trunci, to expose the external abdominal oblique muscle. The external oblique muscle can easily be identified by the caudoventral direction of its fibers.

Bluntly dissect through it to expose the cranioventral fibers of the internal oblique muscle. Continue the dissection through the internal abdominal oblique and the underlying transversus abdominous muscle. Continue the incision through retroperitoneal fat to expose the kidney and renal vessels. Gently dissect the tissue cranial to the hilus of the kidney and identify the renal vessels. Take care not to damage the ureter exiting caudolaterally. Locate the renal artery and place a silk suture around it. Note that the renal artery often bifurcates. Make sure that there isn't another branch.

Dog Renal Artery: Chronic Blood Flow Measurement Cont.

Place a 3 mm Probe around the artery (or paired arteries) and close the sliding bracket. Securing the Probe takes special care because the kidney is mobile and suspended by the vascular pedicle. The objective is to fix the position of the Probe with respect to the artery without making the Probe support the weight of the kidney. Suture the cable to the body wall close to the point where the renal artery joins the aorta. This position minimizes the strain on the cable when the kidney moves. Place sutures through the bracket suture holes to adjacent connecting tissue. These sutures will limit rotation of the Probe around the artery. Wrapping the Probe with silicone sheet wrap is recommended to stabilize the implant.

Pass the cable through the incision and close each layer of the body wall independently. Create a subcutaneous pouch for the cable and connector. Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

When handling chronic instrumentation, cables and connectors can be readily exteriorized at the time of implantation surgery or kept in a subcutaneous pouch until flow data recording is desired. In this protocol, cable and connector were kept in a subcutaneous pouch. Fibrotic tissue effectively seals the tunnel containing the cable within seven days post surgery. Whenever blood flow data is required, the cable and connector can be exteriorized under a light anesthesia procedure.

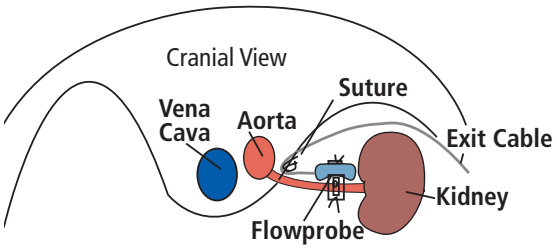

Fig. 2: Schematic of anatomical site, cranial view

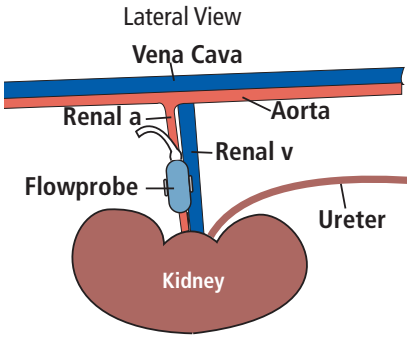

Fig. 3: Schematic of anatomical site, lateral view

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Dog Superior Mesenteric Artery and Portal Vein: Acute Blood Flow Measurement

APPLICATION BASICS

Site:	Superior mesenteric artery
Species:	Dog
Weight:	16 - 20 kg
Duration:	Acute
Vessel Diameter:	3 mm

PROBE

Size:	4 mm (side exit)
Reflector:	L with sliding cover
Other:	Silicone Wrap
Catalog #:	MA-4PSS-LS-WC100-CM4B-GA

FLOWMETER	TS420 Perivascular Module

APPLICATION BASICS

Site:	Portal vein
Species:	Dog
Weight:	16 - 20 kg
Duration:	Acute
Vessel Diameter:	12 mm

PROBE

Size:	12 mm (side exit)
Reflector:	U with Silicone Shield
Cable Length:	1 meter
Catalog #:	MA-12PSS-USW-WC100-CRS10-GA

FLOWMETER	TS420 Perivascular Module

Application

This protocol was developed to study the effect of neuro peptides in splanchnic flow. In one study, measurements of portal and mesenteric flow were combined with pancreatic capillary blood flow from a laser Doppler flowmeter. In another study, the pancreatic duct was cannulated to determine pancreatic juice volume and protein output.

Flow Ranges Observed

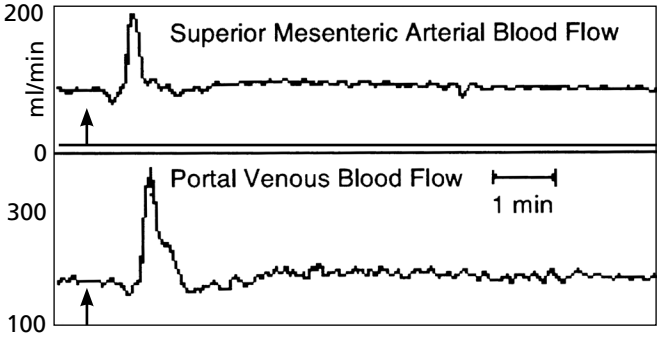

Fig. 1: Recording of superior mesenteric arterial blood flow and portal venous blood flow, and their responses to 0.1 µg/kg of kassinin (arrow).

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

With anaesthetized dog in dorsal recumbency, make a midline skin incision from the xiphoid cartilage to the umbilicus. Continue the incision through the linea alba and the peritoneum to expose the lobes of the liver. Deflect the lobes of the liver cranially and identify the splanchnic vessels.

Carefully dissect free a 2 cm segment of the portal vein and strip all fat from it for proper ultrasonic (acoustic) transmission. Slip the large U bracket around the vein. Attach the body of the Probe and secure the screws. Rotation of the Probe around the vein may be necessary to align the screwdriver with each screw. Suture the cable to the perivascular connective tissue. Identify the superior (cranial) mesenteric artery.

Dog Superior Mesenteric Artery and Portal Vein: Acute Blood Flow Measurement Cont.

Gently strip away the mesenteric tissue to expose the artery. Strip all fat and pass the L bracket around the artery, close the slide and secure the screws. Suture the cable to perivascular tissue.

Remove the plunger of a 30 cc syringe and load the syringe with sterile acoustic gel. Make a special effort to prevent the formation of air bubbles. One technique is to top the syringe and let the gel flow down the side of the syringe. Using a flexible catheter on the tip of the syringe, liberally deposit gel between each Probe bracket and the respective artery. Press the test mode button on the meter to verify that signal amplitude is above 0.6 V. A low signal or an acoustic error can usually be traced to an insufficient amount of acoustic gel or to an air bubble.

Note that blood flow measurements were performed under anesthesia agents, which is known to affect cardiovascular parameters when compared to measurements in conscious animals.

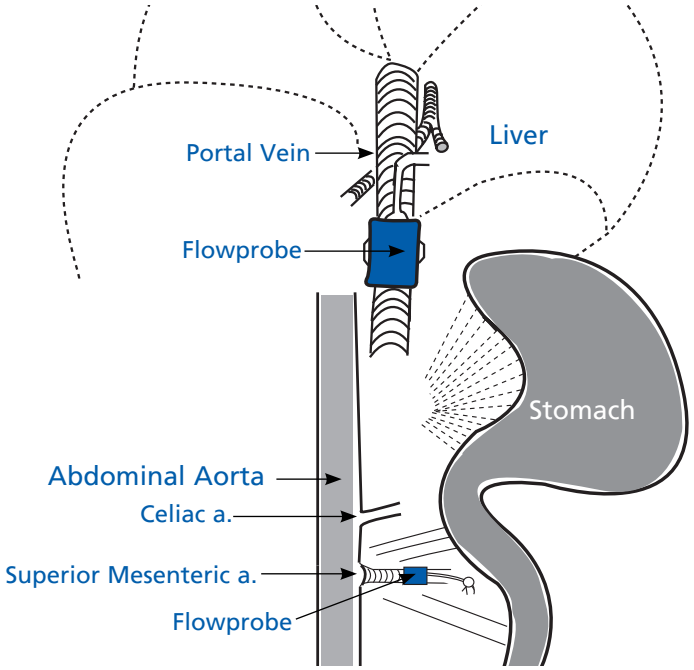

Fig. 2: Schematic of anatomical site

If performing a survival procedure, close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

ACKNOWLEDGEMENT

Dr. Shoichiro Sumi, Dr. Kazutomo Inoue, Dr. Masafumi Kogire, Dr. Ryuichiro Doi, Dr. Kyoichi Takaori, Dr. Takashi Suzuki, and Dr. Takayoshi Tobe, First Department of Surgery, Faculty of Medicine, Kyoto University. Sakyo-ku, Kyoto 606, Japan. Dr. Haruaki Yajima, Faculty of Pharmaceutical Sciences, Sakyo-ku, Kyoto 606, Japan.

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Horse Cecal Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Lateral cecal artery
Species:	Horse
Weight:	400 kg
Duration:	Chronic
Vessel Diameter:	3 - 4 mm

PROBE

Size:	4 mm (side exit)
Reflector:	L with sliding cover
Cable Length:	1 meter
Other:	Skin button
Catalog #:	MC-4PSS-LS-WC100-CM4S-GC

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

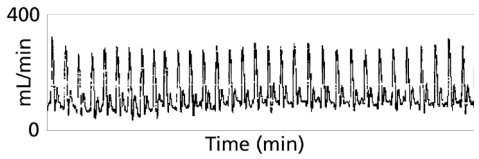

Fig. 1: Instantaneous flow in the lateral cecal artery in a conscious healthy horse ranges from 80 to 320 ml/min.

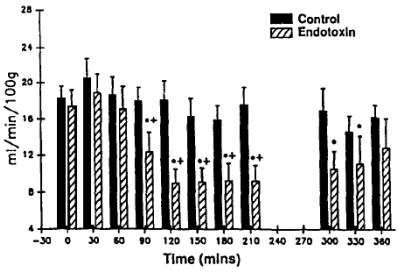

Fig. 2: Lateral cecal arterial blood flow after infusion of saline solution (control) or endotoxin (0.03 µg/kg/bwt).

Application

This protocol was developed to study the pathogenesis of equine colic. In these investigations, intestinal motility is often measured with extraluminal strain gauges. In one experiment, the simultaneous measurement of blood flow and contractile activity was used to study the effect of endotoxin.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

While not necessary for the approach to the cecum, rib resection is routinely used. This approach results in fewer postoperative incisional problems than when the incision is made lower in the paralumbar fossa. Place the horse in left lateral recumbency.

Make a skin incision over the last rib. Continue the incision to expose the 18th rib. Transect the rib proximally, disarticulate it at the costochondral junction and remove it. Open the peritoneum to expose the viscera.

Exteriorize the cecum, and palpate the lateral band to locate the lateral cecal artery. Dissect out a 3 cm segment of the artery. Place the Flowprobe around the artery. Close the slide and secure it. Place a single suture in each of the two bracket eyelet holes to anchor the Probe to cecal tissue. Place another suture around the cable close to the body of the Probe.

Horse Cecal Artery: Chronic Blood Flow Measurement Cont.

Make a stab incision in the abdominal wall dorsal to the original incision. Continue the exit path with a subcutaneous tunnel to the skin button high on the body wall. The skin incision required for insertion of the skin button should be sutured and stabilized and sealed with appropriate material and technique. Sealing decreases the incidence of infections around the cable.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

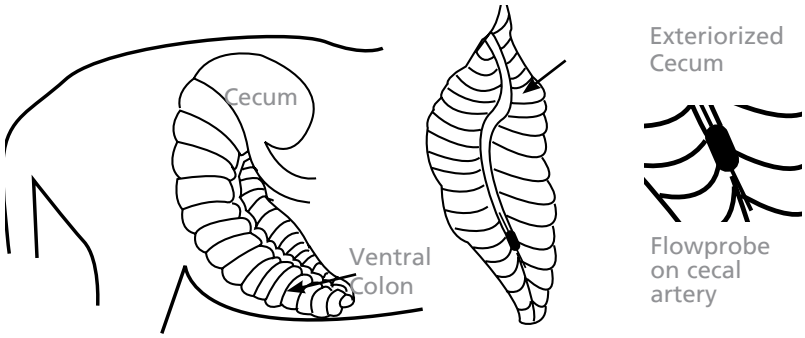

Fig. 3: Schematic of anatomical site

ACKNOWLEDGEMENT

SURGERY: Dr. ES Clark and Dr. JN Moore, Dept. of Large Animal Medicine, College of Veterinary Medicine, Univ. of Georgia, Athens, GA

SKIN BUTTON: Dr. H.P. Hackett , and Dr. A. Dobson, New York State College of Veterinary Medicine, Cornell University, Ithaca, NY 14853

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Horse Colic Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Colic branch, Ileo-colic artery
Species:	Horse (Pony)
Weight:	160 kg
Duration:	Chronic
Vessel Diameter:	5 - 7 mm

PROBE

Size:	8 mm (side exit)
Reflector:	L with sliding cover
Cable Length:	60 cm
Catalog #:	MC-8PSS-LS-WC60-CRS10-GC

FLOWMETER

TS420 Perivascular Module

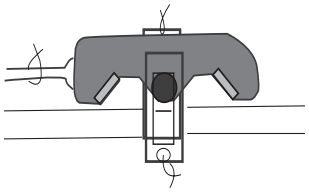

Fig. 1: Flowprobe sutured to colic branch of ileo-colic artery.

Application

This protocol was developed to study the pathogenesis of equine colic. In these investigations, a fistula in the left ventral colon, near the fusus coli is often useful. This is performed in two stages: a colonopexy is followed by fistulation 7-10 days later. Colic arterial flow has also been used to evaluate the effects of serotonin, substance P and alpha 2 adrenergics on the equine large colon.

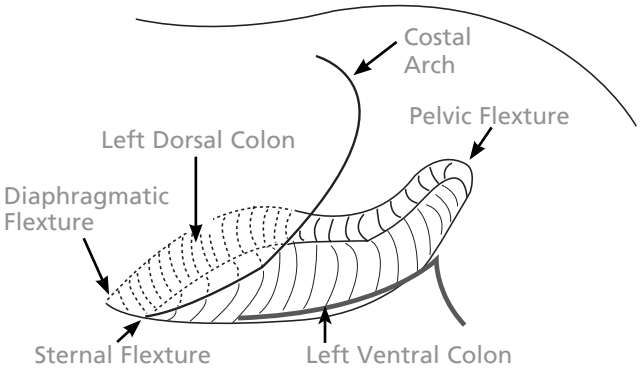

Fig. 2: Anatomical site.

Surgical Protocol

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place the horse in right lateral recumbency. Make a skin incision parallel to the last rib. Identify the ventral and dorsal colic arteries in the region of the sternal flexture.

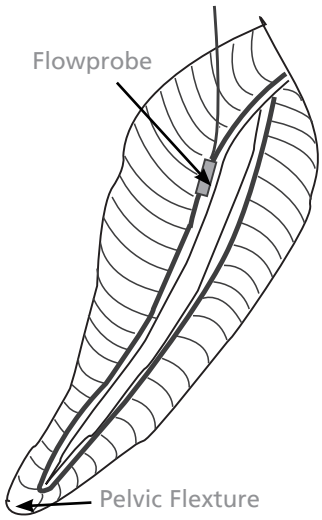

Fig. 3: Flowprobe on colic branch of ileo-colic artery.

transonic
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Horse Colic Artery: Chronic Blood Flow Measurement Cont.

Both arteries are accessible and Flowprobes may be implanted on either or both. Choose a location with enough loose connective tissue to cover the Probe and carefully dissect out the desired artery from the mesocolic bands, taking care to avoid nerve fibers. Prepare the Flowprobe by installing a silicone sleeve over the cable where it will pass through the skin. Place the Probe around the artery. Close the slide and secure it. Place a single interrupted suture in each of the bracket eyelet holes. Fold a flap of connective tissue over the Probe and suture it in place. Make a stab incision in the abdominal wall dorsal to the original incision. Continue the exit path with a subcutaneous tunnel to a high exit incision caudal to the 18th rib. Place a horizontal mattress suture around the cable and sleeve to keep the cable from sliding back and forth.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

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Dr. Pam Wilkens, Equine Clinic at Oakencroft, Ravena, NY

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Horse Uterine Artery: Acute Blood Flow Measurement

APPLICATION BASICS

Site:	Middle Uterine Artery
Species:	Horse
Weight:	500 kg
Duration:	Acute
Vessel Diameter:	5 - 7 mm

PROBE

Size:	8 mm
Reflector:	L with sliding cover
Cable Length:	60 cm
Catalog #:	MA-8PSS-LS-WC60-CRA10-GA

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

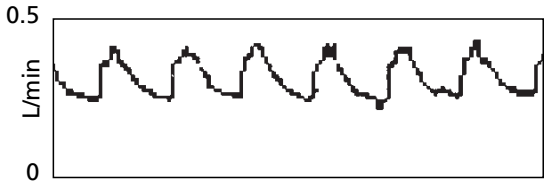

Fig. 1: Mean uterine flow in the anesthetized thoroughbred mare was 350 ml/min.

Application

This protocol was developed as part of an investigation on fetal and maternal relationships in parturition in the mare. Horses undergoing surgery often have circulatory complications such as perfusion mismatches, ischemic myopathy and low blood oxygen levels. In pregnant mares, emergency surgery is commonly associated with premature parturition and increased foal mortality.

In this study, uterine blood flow was measured in late pregnancy mares undergoing abdominal surgery for fetal instrumentation. This data was used intraoperatively to monitor the effects of the mare's positioning and the length of time under anesthesia. Comparisons were also made between different anesthetic agents such as isofluorane and halothane. This technique will also be used to characterize the interactions between uterine blood flow and common therapeutic agents such as altrenogest, clenbuteral, oxytocin and flunixin-meglumine.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Make a ventral midline incision from a point 6 cm cranial to the umbilicus to the udder with electrocautery. Continue the incision through the subcutaneous tissues with a #10 blade and enter the peritoneum. Identify the nonpregnant horn of the uterus by palpation and manipulate the uterus to expose the middle uterine artery. Dissect free the covering fascia to mobilize a short (1-2 cm) segment of the artery.

Pass the L bracket of the Probe around the middle uterine artery. Close the slide and secure the screw. Remove the plunger of a 30 cc syringe and load with sterile surgical lubricating gel, taking care to prevent the formation of air bubbles. Place a flexible catheter on the tip of the syringe. The catheter may be inserted into the Probe's acoustic window adjacent to the vessel and the gel deposited as the syringe is withdrawn.

To verify that signal amplitude is above 0.6 V, press the test mode button on the Meter. A low signal or an acoustic error can usually be traced to an insufficient amount of lubricating gel or an air bubble. If the artery fills most of the acoustic window, surface tension will keep the acoustic couplant between the vessel and the Flowprobe and the uterus may be returned to the abdomen while other procedures are performed. When fetal surgery is included in the protocol, it is suggested to administer antibiotic directly to the fetus before closing.

Horse Uterine Artery: Acute Blood Flow Measurement Cont.

When all procedures are completed, remove the Flowprobe. Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

ACKNOWLEDGEMENT

Dr. Claire Card, Dr. Etta Wertz, NYS College of Veterinary Medicine, Cornell University, Ithaca, NY

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Other Species, Uterine Artery

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Baumann A et al,"Maternal and Fetal Effects of Milinone and Dopamine," Am Soc Anes Abstr 1989; 71(3A): A854.

Akagi K et al, "Ultrasonic Transit-Time Measurement of Blood Flow in the Animal Chronic Preparation Model," Jpn J Med. Ultrasonics 1987; 14(2): 26-32.

Horses, Other Organs

Clark ES et al, "The Effects of Xylazine Administration on Cecal Mechanical Activity and Cecal Blood Flow in Healthy Horses," Am J Vet Res 1988; 49(5): 720-721..

Clark ES, Moore JN, "The Effects of Dopamine Administration on Cacal Mechanical Activity and Cecal Blood Flow in Conscious Healthy Horses," Am J Vet Res 1989; 50(7): 1084-88.

Pig Celiac Artery: Acute Blood Flow Measurement

APPLICATION BASICS

Site:	Celiac artery
Species:	Pig
Weight:	15 - 25 kg
Duration:	Acute
Vessel Diameter:	3 mm
PROBE	
Size:	4 mm (back exit)
Reflector:	L with sliding cover
Connector:	10-pin
Cable Length:	60 cm
Catalog #:	MC-4PSB-LS-WC60-CRA10-GA
FLOWMETER	TS420 Perivascular Module

Flow Ranges Observed

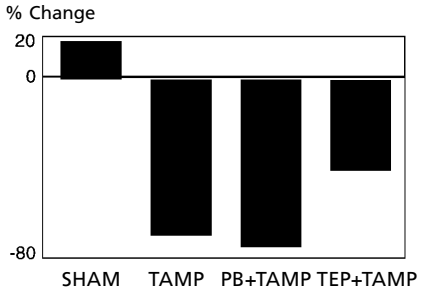


Fig. 1: Celiac arterial blood flow. Baseline mean celiac arterial flow in the anesthetized pig was 37 ml/min/100g of tissue supplied by the celiac axis.

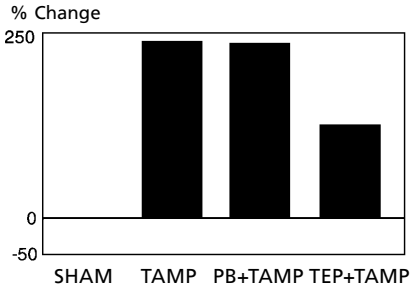


Fig. 2: Celiac arterial resistance.

Application

This protocol was developed in studies of the hemodynamic basis for gastric stress ulceration secondary to cardiogenic shock. Cardiogenic shock was induced with mild hemorrhage and cardiac tamponade. Cardiac output was then measured and maintained at a given fraction of baseline by varying the severity of the cardiac tamponade. This model produces reproducible and stable levels of cardiogenic shock with severe splanchnic vasoconstriction and gastric lesions strikingly similar to those seen in patients with "stress ulceration."

Pigs with alpha adrenergic blockade were compared to pigs with ablated renin-angiotensin axis; alpha adrenergic ablation failed to significantly alter the characteristic response while blockade of the renin-angiotensin axis substantially ameliorated both the ischemia and vasospasm seen in the celiac bed. While moderate gastric vasoconstriction during shock favors survival, hyper-responsiveness causes ischemia that exacerbates the process, terminating in a positive feedback cycle that is inevitably fatal. The researcher concluded that this syndrome might be treated or prevented with pharmacological blockade of the renin-angiotensin axis.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place anesthetized pig in right lateral recumbency and make a 4 cm vertical skin incision just caudal to the last rib. Extend the skin incision through the cutaneous, latissimus dorsi, external abdominal oblique, internal abdominal oblique and transverse abdominal muscles

Pig Celiac Artery: Acute Blood Flow Measurement Cont .

Care is taken not to incise the peritoneum. Trace the aorta cranially to identify and dissect free the root of the celiac artery. Taking care not to disturb the perivascular sheath, remove fatty tissue and pass the L bracket of the Probe around the celiac artery. Close the slide and secure the screw. If there is sufficient connective tissue, the Probe may also be sutured in position. Remove the plunger of a 30 cc syringe and load the syringe with sterile acoustic gel, taking care to prevent the formation of air bubbles. Place a flexible catheter on the tip of the syringe; the catheter may be inserted into the Probe's acoustic window adjacent to the vessel and the gel deposited as the syringe is withdrawn.

If performing a survival procedure, close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

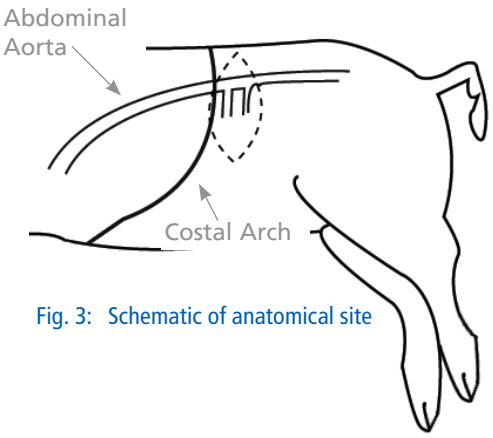


Fig. 3: Schematic of anatomical site

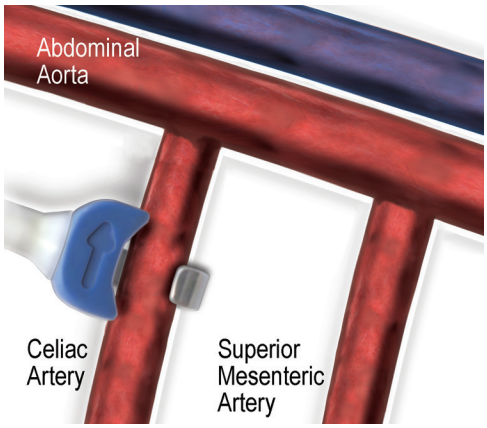


Fig. 4: Flowprobe placement

ACKNOWLEDGEMENT

Dr. Robert W. Bailey, Dept. of Surgery, University of Maryland Hospital, 22 South Green St. Baltimore MD.

REFERENCE

Bailey RW, Bulkley GB, Hamilton SR, Morris JB, Haglund UH, Meilahn JE, "The Fundamental Hemodynamic Mechanism Underlying Gastric 'Stress Ulceration' in Cardiogenic Shock." Annals of Surg 1987; 205: 597-612.

Pig Superior Mesenteric Artery: Acute Blood Flow Measurement

APPLICATION BASICS

Site:	Superior mesenteric artery
Species:	Pig
Weight:	15 - 25 kg
Duration:	Acute
Vessel Diameter:	3 mm

PROBE

Size:	4 mm (back exit)
Reflector:	L with sliding cover
Connector:	10-pin
Cable Length:	60 cm
Catalog #:	MC-4PSB-LS-WC60-CRA10-GA

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

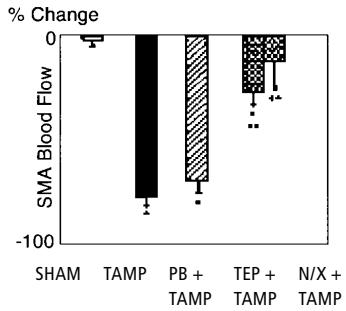


Fig. 1: Response of superior mesenteric arterial blood flow to cardiac tamponade.

Application

This protocol was developed in studies of the hemodynamic basis for gastric stress ulceration secondary to cardiogenic shock. Cardiogenic shock was induced with mild hemorrhage and cardiac tamponade. Cardiac output was then measured and maintained at a given fraction of baseline by varying the severity of the cardiac tamponade. This model produces reproducible and stable levels of cardiogenic shock with severe splanchnic vasoconstriction and gastric lesions strikingly similar to those seen in patients with “stress ulceration”.

Pigs with alpha adrenergic blockade were compared to pigs with ablated renin-angiotensin axis; alpha adrenergic ablation failed to significantly alter the characteristic response while blockade of the renin-angiotensin axis substantially ameliorated both the celiac bed ischemia and vasospasm. While moderate gastric vasoconstriction during shock favors survival, hyper-responsiveness causes ischemia that exacerbates the process, terminating in a positive feedback cycle that is inevitably fatal. Researchers concluded that this syndrome might be treated or prevented with pharmacological blockade of the renin-angiotensin axis.

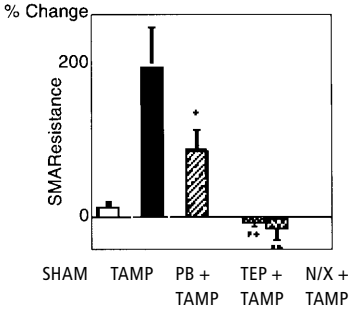


Fig. 2: Response of superior mesenteric resistance to maximum cardiac tamponade.

Pig Superior Mesenteric Artery: Acute Blood Flow Measurement Cont.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place anesthetized pig in right lateral recumbency and make a 4 cm vertical skin incision just caudal to the last rib. Extend the skin incision through the cutaneous, latissimus dorsi, external abdominal oblique, internal abdominal oblique and transverse abdominal muscles. Care is taken not to incise the peritoneum.

Trace the aorta cranially to identify and dissect free the root of the superior mesenteric artery. Taking care not to disturb the perivascular sheath, remove fatty tissue and pass the L bracket of the Probe around the superior mesenteric artery. Close the slide and secure the screw. If there is sufficient connective tissue, the Probe may also be sutured in position. Remove the plunger of a 30 cc syringe and load the syringe with sterile acoustic gel, taking care to prevent the formation of air bubbles. Place a flexible catheter on the tip of the syringe; the catheter may be inserted into the Probe's acoustic window adjacent to the vessel and the gel deposited as the syringe is withdrawn.

If performing a survival procedure, close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

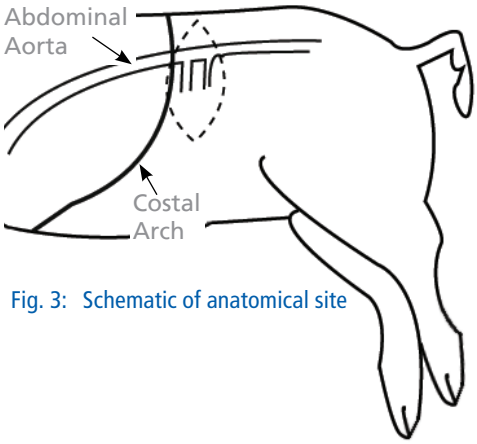


Fig. 3: Schematic of anatomical site

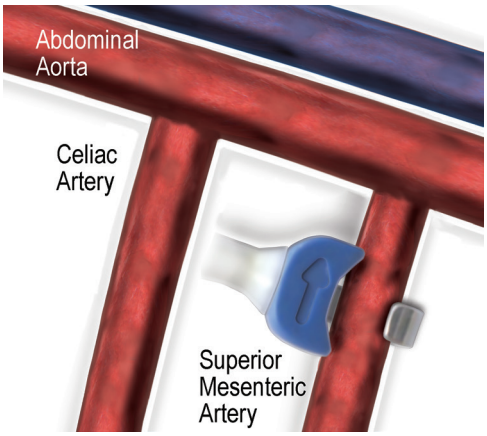


Fig. 4: Flowprobe placement

ACKNOWLEDGEMENT

Dr. Robert W. Bailey, Dept. of Surgery, University of Maryland Hospital, 22 South Green St. Baltimore MD.

REFERENCE

Bailey RW, Bulkley GB, Hamilton SR, Morris JB, Haglund UH, "Protection of the Small Intestine from Nonocclusive Mesenteric Ischemic Injury Due to Cardiogenic Shock," Am J of Surg 1987; 153: 108-116.

Rabbit Auricular Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Auricular artery
Species:	Rabbit, NZ White
Weight:	3.5 - 4 kg
Duration:	Chronic
Vessel Diameter:	1 mm
PROBE	
Size:	1 mm
Reflector:	L with sliding cover
Cable Length:	60 cm
Catalog #:	MC-1PRB-LS-WC60-CM4S-GC
FLOWMETER	TS420 Perivascular Module

Application

The rabbit ear has been used as a longitudinal model for the study of human digital pathophysiology.

Surgical Approach

PREPARATION

Before instrumenting the rabbit, acclimate the animal to a restrainer for a week with repeated restraint conditioning of increasing durations for up to an hour.

INSTRUMENTATION

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Isolate the auricular artery carefully from the neurovascular bundle on the dorsal, basal portion of the ear and place the artery within the lumen of a 1PRB Flowprobe (Fig. 2). Hold the Probe in place with cyanoacrylate glue (Nexaband®, Tri-Point Medical, Raleigh, NC). From the Probe head, pass the Probe cable and connector beneath the skin down the base of the ear, across the top of the cranium and out through a cylindrical anchor attached to the rabbit's skull (Fig. 3).

Close the incisions using appropriate suture and technique. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

MEASUREMENTS

Place the rabbit in a restrainer, remove the screw-on cap of the electrical connector and connect the Flowprobe to the transit-time Flowmeter and begin measurements recording.

Flow Ranges Observed

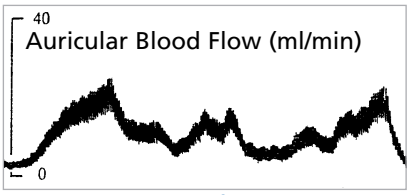


Fig. 1: Auricular blood flow in a conscious rabbit seven days after surgical implantation of the Flowprobe. Range: < 1 - 25 ml/min.

Fig. 2: Transit-time Flowprobe positioned over the rabbit auricular artery and held in place with cyano-acrylate glue applied over a Dacron mesh (cross-hatched).

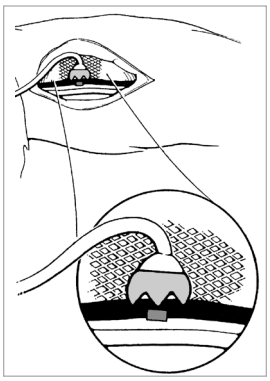
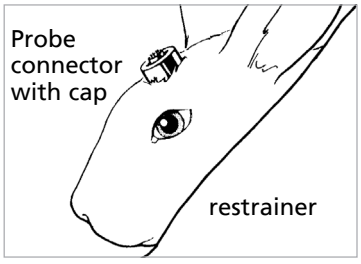


Fig. 3: Exit site at top of skull for the transit-time Probe connector with cap.



ACKNOWLEDGEMENT

Protocol and data courtesy of Dr. Tom L. Smith, Wake Forest University, Bowman Gray School of Medicine, Department of Orthopedic Surgery, 300 S. Hawthorne Rd., Winston-Salem, NC 27103-2708

REFERENCES

Smith TL, Korman LA, "Development of a New Rabbit Ear Model for Longitudinal Study of Digital Pathophysiology," Microsurgery 1992; 13: 325-331.

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Rabbit Renal Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Renal artery
Species:	Rabbit
Weight:	3 - 3.5 kg
Duration:	Chronic, (<12 months)
Vessel Diameter:	1 mm

PROBE

Size:	2 mm (side exit)
Reflector:	J with sliding cover
Connector:	4-pin
Cable Length:	60 cm
Catalog #:	MC-2PSB-JS-WC60-CM4B-GC

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

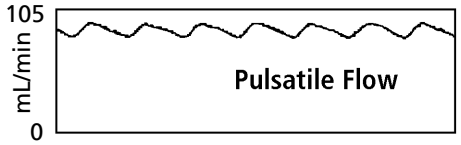

Fig. 1: Flow range: 75-90 ml/min.

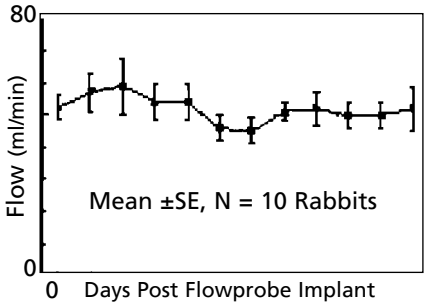

Fig. 2: Compiled from 10 chronically instrumented rabbits weighing between 3.0 and 3.5 Kg.

Application

The measurement of renal blood flow has an important role in research on hemodynamics, electrolyte regulation and pregnancy induced hypertension. This protocol was used to study the interactions of angiotensin II and a cyclooxygenase inhibitor. Flow-pressure relationships are essential in defining renal autoregulation. Other studies have focused on diuretics, cardiovascular drugs, and nephrotoxic agents. While average renal flow may also be obtained from the renal vein, the pulsatile waveform of the renal artery provides additional information and visual confirmation of a functioning chronic implant.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Shave the midscapular region as well as the left flank. Position the anesthetized rabbit in right lateral recumbency. Scrub the area and make a 6 cm skin incision starting 2 cm below the last rib and 2 cm lateral to the spine. Use a needle driver to make a subcutaneous tunnel from this incision to the midscapular area.

Make a second skin incision in the midscapular area and pull the 2PSB Probe, with sliding cover and bracket removed, through the subcutaneous tunnel to the primary incision (left flank). Gently separate the abdominal muscles to expose the retroperitoneal fat and the left kidney. Retract the fatty tissue and kidney laterally, and carefully dissect free a 0.5 cm segment of the renal artery and vein as distal from the kidney as possible. Slide a precut silicone sheet with round edges and with top sutures in place beneath both artery and vein. Then slide the Probe around the artery, close and secure the sliding bracket. The proximal ends of the silicone sheet are brought up around the Probe cable and sutured.

Rabbit Renal Artery: Chronic Blood Flow Measurement Cont.

Sutures are also placed on the lateral sides of the silicone sheet. The silicone sheet has two functions; it keeps fat, a poor acoustical couplant, from infiltrating into the window. It also supports the Probe and helps avoid the pressure points that irritate the vessel.

While closing the incision, make sure to leave enough slack in the cable and secure it to the superficial muscle layer.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

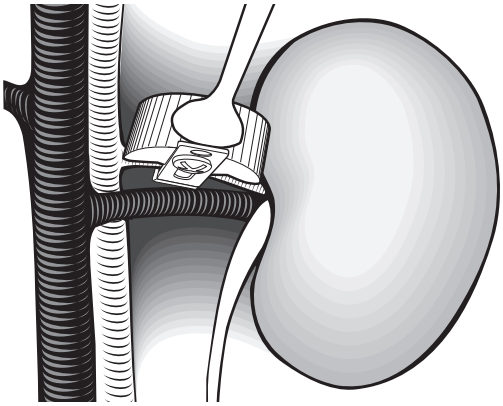

Fig. 3: Flowprobe applied to renal artery.

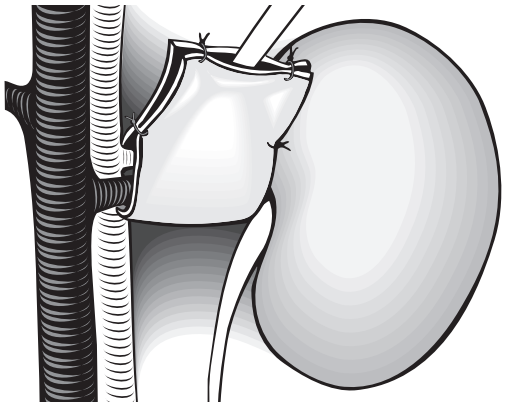

Fig. 4: Flowprobe wrapped in silicone sheath.

ACKNOWLEDGEMENT

Dr. G. Brown, Dr. R. Venuto, with technical assistance of A. Ingeana and J. Helinski. State University of New York at Buffalo, Kimball Tower, 3435 Main Street. Buffalo, NY 14214, Departments of Nursing and Medicine.

REFERENCES

Brown GP, Venuto RC., "Measurement of Renal Blood Flow of Conscious Rabbits Utilizing Ultrasonic Flowprobes: The Effect of Cyclooxygenase Inhibition," Central Society for Clinical Research 1989; 37: 950A.

Sheep Carotid Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Carotid artery
Species:	Sheep
Weight:	40 kg
Duration:	Chronic
Vessel Diameter:	6 - 8 mm

PROBE

Size:	8 mm (side exit)
Reflector:	L with sliding cover
Connector:	10-pin
Cable Length:	60 cm
Catalog #:	MC-8PSS-LS-WC60-CRA10-GC

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

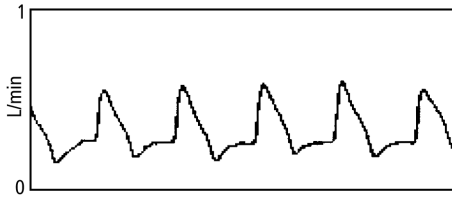

Fig. 1: Instantaneous flow in the carotid artery ranged from 0.15 to 0.55 l/min.

Application

This protocol was developed for the early validations of transit-time technology. In some experiments, the carotid artery was completely exteriorized in a skin loop and a cannula was installed. The carotid artery is also a convenient location for the installation of vascular access ports and pressure catheters.

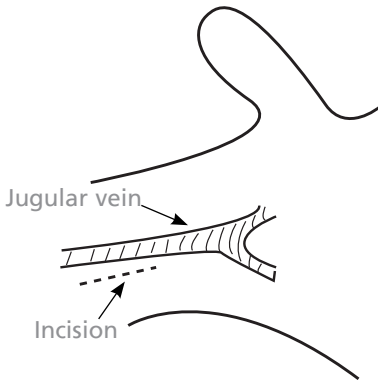

Fig. 2: Schematic of anatomical site

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Have a non sterile assistant compress the vein at the thoracic inlet so that the jugular vein may be visualized. Make a 5 cm skin incision ventral to the jugular vein as shown in Figure 2. Palpate for the pulsating artery and separate the sternomastoideus and cleidomastoideus muscle to expose the carotid sheath. Carefully incise the sheath and separate the vagus nerve from the common carotid artery. Place the L bracket of the Probe around the artery. Close the slide and secure the screw.

Appose the separated muscle layers with 2-0 non-absorbable suture as shown in the figure on the next page. Secure the Probe with sutures through the holes in the bracket and around the cable as shown in Figure 4. Create a subcutaneous tunnel to a second skin incision 5 cm from the dorsal midline of the neck. Pass the cable through the subcutaneous tunnel and exteriorize with a skin button.

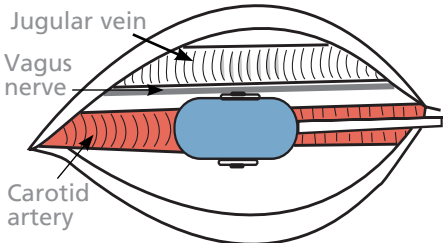

Fig. 3: Schematic of flowprobe placement

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Sheep Carotid Artery: Chronic Blood Flow Measurement Cont.

Close the skin with simple interrupted sutures. Also close the stab incision and the cable exit site with simple interrupted sutures. Suture the cable to the skin for strain relief and close the incision at the cable exit site. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

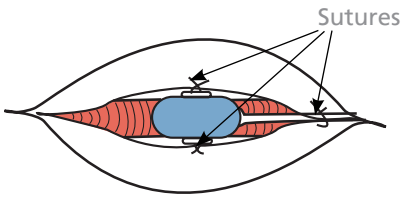

Fig. 2: Schematic of suture locations

ACKNOWLEDGEMENT

Dr. Alan Dobson, Department of Physiology, NYS College of Veterinary Medicine, Cornell University, Ithaca, NY 14853

REFERENCES

Burton, R.G. and Gorewit, R.C., "Ulltrasonic Flowmeter - Uses Wide-Beam Transit-time Technique," Medical Electronics, 1984; 15(2): 68-73.

Drost CJ, Dobson A, Sellers AF, Barnes RJ, Comline RS, "An Implantable Transit-Time Ultrasonic Flowmeter for Long Term Measurement of Blood Volume Flow", Federation Proceedings, 1984; 43(3) 538.

Dougherty RW, "Experimental Surgery in Farm Animals," Iowa State University Press, Ames 1981.

Sheep Simultaneous Coronary Flow & NMR Spectroscopy: Acute Blood Flow Measurement

APPLICATION BASICS

Site:	Coronary sinus shunt
Species:	Sheep: 5 - 90 days old
Weight:	5 - 14 kg
Duration:	Acute
SENSOR	
Size:	3 mm (Inline)
Cable Length:	1 meter
Extension Cable:	4 meter
Catalog #:	ME-3PXN (non-magnetic)
FLOWMETER	TS410 Tubing Module

Flow Ranges Observed

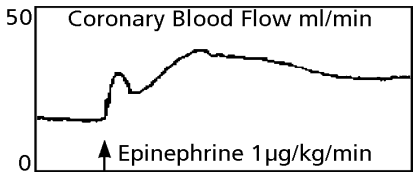

Fig. 1: Typical recording of hemodynamic parameter (coronary bf) obtained while acquiring ^{31}PNMR spectra.

Application

This protocol was developed to correlate the traditional technique of measuring oxygen consumption (ie, the product of concentration and flow) with ATP utilization as measured with NMR spectroscopy. The simultaneous measurement of blood flow with NMR presents some unique challenges. First, the Flowsensor must be completely constructed from non-magnetic materials. Special care must also be taken to minimize the noise introduced into the NMR signal by the flow system. In this protocol, both spatial isolation and electrical filtering were used to increase the signal-to-noise ratio. Finally, the signal-to-noise ratio is increased by gating data acquisition to the initial inspiratory phase of the respiratory cycle and summing 60 acquisitions. In two animals, this concept was taken even further and the heart was paced at a precise harmonic of the ventilation rate.

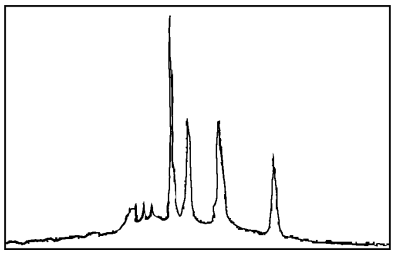

Fig. 2: ^{31}P (81 MHz) spectrum of a lamb left ventricle (age, 70 days) *in vivo*. The spectrum represents the sum of 300 acquisitions which were respiratory gated resulting in an interpulse delay of 2 sec.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Perform a left thoracotomy with rib removal to expose the left ventricle. Identify the left azygous vein draining into the coronary sinus, and ligate it as shown in Fig. 3 to keep it from contributing to apparent coronary flow. Make a shallow skin incision over each jugular vein and catheterize each vein with 1/8 inch Tygon tubing. Advance one catheter into the right atrium and the other into the coronary sinus as shown in Fig. 4. Place a suture around the coronary sinus so that all coronary drainage must pass through the catheter.

Sheep Simultaneous Coronary Flow & NMR Spectroscopy: Acute Blood Flow Measurement Cont.

Connect one of the jugular catheters to the cannulating Flowsensor and the other jugular catheter to other port of the T connector as shown in Fig. 5. The stem of the T connector can be used for blood sampling or heparin flushing of the shunt.

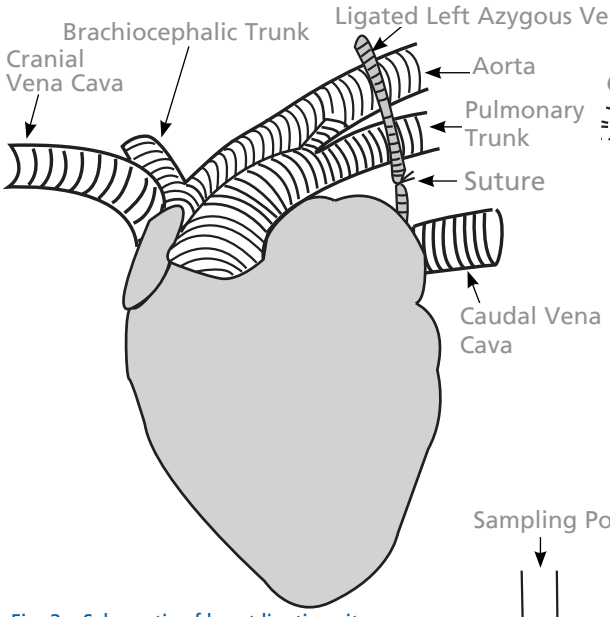

Fig. 3: Schematic of heart ligation site

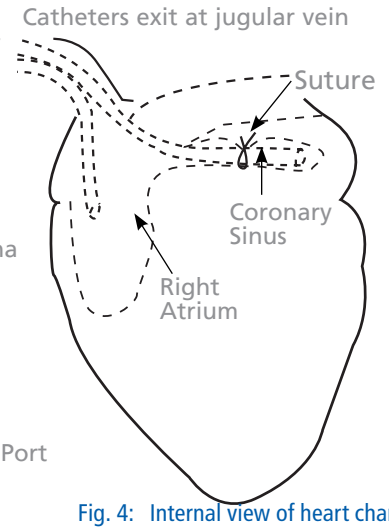

Fig. 4: Internal view of heart chambers

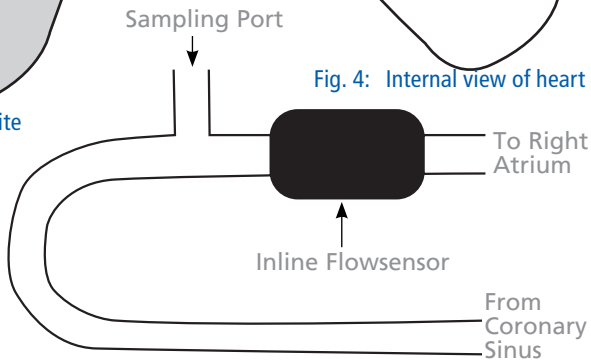

Fig. 5: Schematic of sensor set-up

ACKNOWLEDGEMENT

Dr. R.S. Balaban and F.W. Heineman, Laboratory of Cardiac Energetics, National Heart, Lung and Blood Institute, National Institutes of Health, Bethesda, MD, 20892

REFERENCES

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Portman MA, Heineman FW, Balaban RS, "Metabolic Control of Oxygen Consumption in the Developing Heart in Vivo: A ^{31}P NMR Study," JACC 1988; 11(2): 9A.

Sheep Ovarian Artery: Acute Blood Flow Measurement

APPLICATION BASICS

Site:	Ovarian artery
Species:	Sheep
Weight:	40 kg
Duration:	Acute

PROBE

Size:	4 mm (side exit)
Reflector:	U with wide silicone shield
Connector:	10-pin
Cable Length:	1 meter
Catalog #:	MA-4PSS-USW-WC100-CRA10-GA

FLOWMETER

TS420 Perivascular Module

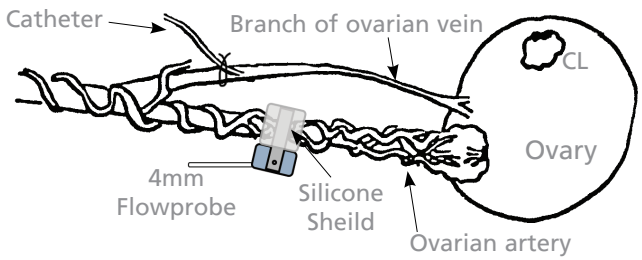

Fig. 1: Location of venous catheter and Flowprobe. The ovarian artery is derived from the aorta and runs a mildly tortuous course close to the surface of the utero-ovarian vein.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place anesthetized ewe in dorsal recumbency and open the abdominal wall by a ventral incision just anterior to the mammary gland, and expose the uterus and ovaries. Dissect a section of the ovarian vascular plexus just above the uterine anastomosis and 4 cm from the ovaries free of connective tissue and separate from major ovarian veins. Place the Flowprobe around the vascular structure as shown in Fig. 1, suture the transducer cable in place, exteriorize via the mid-line incision, and suture the cable to the skin. Close the abdominal wall temporarily during the blood flow measurement.

If performing a survival procedure, close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

REFERENCE

Rabiee RA, Lean IJ, Gooden JM, O.Brien J, " A New Method for Evaluating Ovarian Function in Sheep," Proc. Nutr. Soc. Aust. 17: 224, 1992

Sheep Portal Vein: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Portal vein
Species:	Sheep
Weight:	40 kg
Duration:	Chronic
Vessel Diameter:	15 mm

PROBE

Size:	16 mm (side exit)
Reflector:	U with wide silicone shield
Connector:	10-pin
Cable Length:	1 meter
Catalog #:	MC-16PSS-USW-WC100-CRA10-GC

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

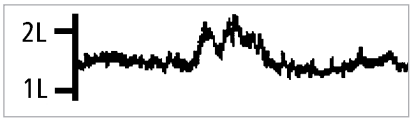

Fig. 1: Total hepatic flow (portal vein & hepatic artery).

Application

Developed for early validations of transit-time technology, this protocol has also been used to study the intestinal uptake of nutrients and hepatic metabolism. The total flux of any metabolite is estimated from the product of concentration and blood flow. In one study, the portal vein and femoral artery were also catheterized to allow periodic collection of blood samples. Hemoglobin and O_2 saturation was measured and used to calculate O_2 concentration. The arteriovenous O_2 difference and portal flow was used to calculate O_2 uptake, an indication of the energy cost of nutrient absorption. Other researchers have measured total hepatic flow by placing a single Probe around the hepatic artery and portal vein.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place anesthetized sheep in left lateral recumbency and make a 15 cm skin incision through the skin and subcutaneous tissues 2 cm caudal to the last rib. Continue the incision through the external abdominal oblique, the internal abdominal oblique and the transverse abdominal muscle.

Trace the tissue between the caudate and right lobes of the liver to locate the portal vein. Free a 3 cm segment of the vein from surrounding tissue taking particular care to remove fat for proper acoustical coupling. Separate the U bracket from the body of the Flowprobe and pass the U bracket around the artery, reposition the body to align with the U bracket and secure both screws. Prevent rotation of the Flowprobe by suturing the cable to the connective tissue around the vein. Suture the silicone shield to perivascular tissue to ensure Probe stability.

Make a stab incision in the abdominal wall dorsal to the original incision. Continue the exit path with a subcutaneous tunnel to an exit incision over the flank.

Sheep Portal Vein: Chronic Blood Flow Measurement Cont.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

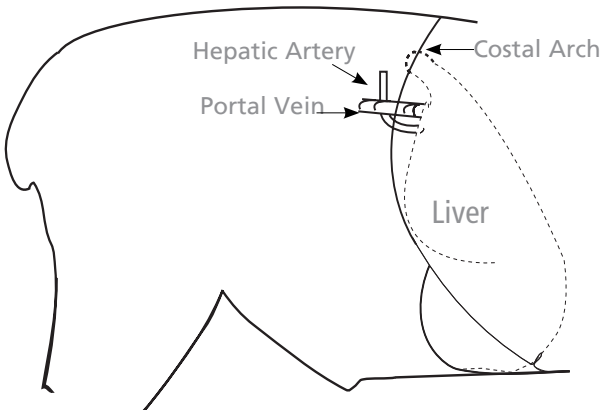

Fig. 2: Schematic of anatomical site

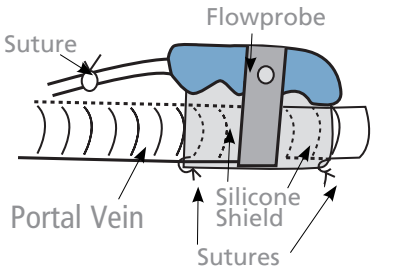

Fig. 3: Schematic of flowprobe placement

ACKNOWLEDGEMENT

Surgery and Total Hepatic Flow Trace

Mr. Bud Reulein and the late Dr. Emmett Bergman, Department of Physiology, New York State College of Veterinary Medicine, Cornell University, Ithaca, NY 14853

Portal Flow Trace

Mr. Steve Neutze, New South Wales Agriculture and Fisheries, Glenfield, New South Wales, 2167

REFERENCES

Neutze SA, Forbes WA, Oddy VH, Gooden JM, "Diurnal Variation in Oxygen Uptake by the Portal System of the Sheep," Proceedings of the Nutrition Society of Australia 1989; 14: 120.

Neutze SA, Forbes WA, Oddy VH, Gooden JM, Edwards SR, Nandra KS, "Calibration of an Ultrasonic Blood Flow Meter in the Sheep," Proceedings of the Nutrition Society of Australia 1989; 14:146, 1989.

Sheep Pulmonary Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Pulmonary artery
Species:	Sheep (Merino)
Weight:	40 - 50 kg
Duration:	Chronic
Vessel Diameter:	16 - 20 mm

PROBE

Size:	20 mm
Connector:	10-pin
Cable Length:	1 meter
Catalog #:	MC-20PAU-WC100-CRS10-GAC

FLOWMETER TS420 Perivascular Module

Flow Ranges Observed

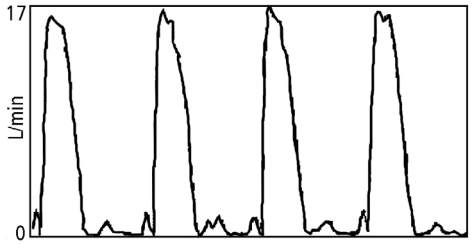

Fig. 1: Instantaneous flow ranges from 0 L/min to 17 L/min.

Application

A PAU-Series COnfidence Flowprobe® placed around the pulmonary artery is useful in any application which requires continuous measurement of cardiac output. The combination of arterial blood pressure and cardiac output provides a continuous measurement of total peripheral resistance.

Fig. 2: PAU-Series COnfidence Flowprobe® with chronic Ultrafit Liner.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

A large area of the left thorax is clipped and prepared as a sterile field, extending from the middle of the back line to the sternum and from the point of the elbow anteriorly caudal almost to the rib line. A skin incision is made above the third left intercostal space and lies approximately in the middle of the flat area of the thoracic wall immediately behind the point of the elbow. The length of the incision depends on the skill of the surgeon but it should be remembered that the PA lies in the dorsal third of the thorax. The muscles of the chest wall are dissected (blunt and with electrosurgical gear) to expose the relevant intercostal space. The third intercostal space is the best choice in Merinos but in more stocky chested animals the fourth often gives better access. Check the spaces by locating the first rib.

A 5 mm midline incision is made through the dorsal third of the intercostal muscle using a combination of scissors and blunt dissection. A longer incision will probably be needed initially until the surgeon is familiar with the anatomy and the position of the PA. Some sort of pediatric rib spreader is needed to give good exposure. A 4 cm incision is made in the pericardium above the PA. Dissect behind the PA to allow access for the Flowprobe. This is probably the most difficult part of the implantation and potentially the most dangerous. Locating the plane of dissection is best done with a gloved finger. Right angle forceps can be used to extend the dissection once we a track is opened behind the vessel but “finger dissection” is the mostly used and recommended technique.

Sheep Pulmonary Artery: Chronic Blood Flow Measurement Cont.

Place the chronic Ultrafit liner around the pulmonary artery rotating the liner so that the opening is on top. Use a pair of straight or right angle forceps to maneuver it around the vessel. Place the body of the Probe over the liner so that the top of the Probe covers the gap in the liner. Secure both Probe and liner with sutures through the suture holes in the liner.

NOTE: FOR DETAILED INTRUCTIONS ON HOW TO PREPARE AND POSITION THE ULTRAFIT LINERS, PLEASE REFER TO THE SURGICAL PROTOCOL " ULTRAFIT LINERS (PAU-SERIES) IMPLANTATION PROTOCOL FOR CHRONIC AORTA OR PULMONARY ARTERY FLOW MEASUREMENTS."

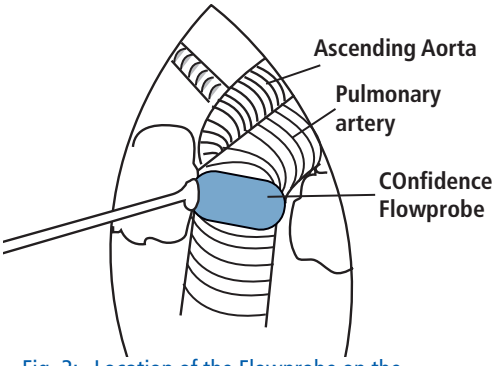

Fig. 3: Location of the Flowprobe on the Pulmonary artery.

The wound is then closed layer to layer with 0 Dexon or equivalent until the subcutaneous fat/fascia layer is left. A coarse purse string suture is placed around the exit of the Flowprobe lead so that, when closed, the suture does not make contact wit the surface of the Probe lead. It is important that the plug and lead are not tunnelled immediately below the skin but slightly deeper beneath the fat/fascia layer. Otherwise the lead can erode through the skin over time. We usually tunnel in two stages almost to the dorsal midline. A 20 cm loop of plastic coated bell wire is inserted using a large needle through a fold of skin immediately above the final lead exit so that approximately 8 cm of the wire is beneath the skin in an anterior/posterior direction. A small leather coin purse with a belt loop is held in position by the looped and knotted wire. The Probe lead plug is inserted into the purse through a hole in the purse back and the hole is closed with a suture. A coarse purse string (0 silk) is placed around the Probe lead at the exit and sutured to the skin purse string. It is important that the lead exit point is behind the back of the purse to minimize the exposed length and the opportunity for the animal to catch the lead with its toe when scratching. The remainder of the fascia and the skin is closed over the wound in the thorax.

Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices .

ACKNOWLEDGEMENT

Dr. J.M. Power BVSc, PhD, Baker Medical Research Institute, Australia

Dr. Margaret Jones, Dr. Rick Rawson and Dr. Peter Nathanielsz, Dept. of Physiology, Laboratory of Pregnancy and Newborn Research NYSCVM, Cornell University, Ithaca NY 14853

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Power JM, Raman J, Dornom A, Farish SJ, Burrell LM, Tonkin AM, Buxton B, Alferness CA, "Passive Ventricular Constraint Amends the Course of Heart Failure: A Study in an Ovine Model of Dilated Cardiomyopathy," Cardiovascular Research, 1999; 44(3): 549-55.

Banerjee MR, Newman JH, "Acute Effects of Atrial Natriuretic Peptide on Lung Mechanics and Hemodynamics in Awake Sheep" Journal of Applied Physiology 1990; 69(2): 728-733.

Bednarik JA, May CN, "Evaluation of a Transit-Time System for the Chronic Measurement of Blood Flow in Conscious Sheep", J Applied Physiol 1995; 78(2): 524-530.

Sheep Splenic Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Splenic artery
Species:	Sheep
Weight:	40 kg
Duration:	Chronic

PROBE

Size:	8 mm (side exit)
Reflector:	L with sliding cover
Connector:	10-pin
Cable Length:	60 cm
Catalog #:	MC-8PSS-LS-WC60-CRA10-GC

FLOWMETER

TS420 Perivascular Module

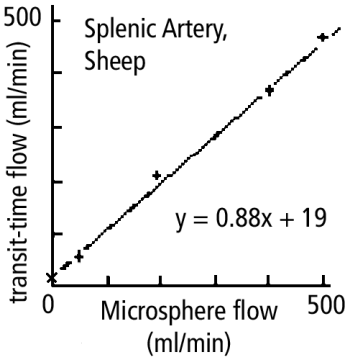

Fig. 1: Blood flow by transit-time ultrasound vs microspheres in the splenic artery, supplying the spleen, abomasum, duodenum, omasum, rumen and reticulum. Anesthetized, +; post-mortem zero, x.

Application

This protocol was developed for the early validations of transit-time technology against radioactive microspheres. Several vessels in the cranial abdomen were studied, including splenic, right ruminal and cranial mesenteric. Similar protocols may also be used to study the ruminal uptake of nutrients. In this technique, the total flux of any metabolite can be estimated from the product of concentration and blood flow.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place anesthetized sheep in right lateral recumbency and make a 15 cm skin incision through the skin and subcutaneous tissues 2 cm caudal to the last rib. Continue the incision through the external abdominal oblique, the internal abdominal oblique, the transverse abdominal muscle and the peritoneum to expose the caudal sac of the rumen. Manually depress the rumen and make a small incision in the bed of the eleventh rib for passing the screwdriver and needle holder.

Manually explore the cranial abdomen from the flank incision. Palpate the cranial sac of the rumen, identify the spleen and locate the splenic artery. Trace the splenic artery over the top of the rumen to locate the other branches of the celiac artery. The right ruminal artery is the first branch encountered. Manually strip the fat from the desired artery and place the Probe around the artery. Close the slide and rotate the Probe so that the screw is directed towards the rib incision. Depress the rumen, pass the screwdriver through the rib incision and tighten the screw. If possible, suture the Probe or the cable to adjacent perivascular connective tissue in the same manner.

Sheep Splenic Artery: Chronic Blood Flow Measurement Cont.

Pass the cable through the rib incision, and create a subcutaneous tunnel to the exit site in the paralumbar fossa.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

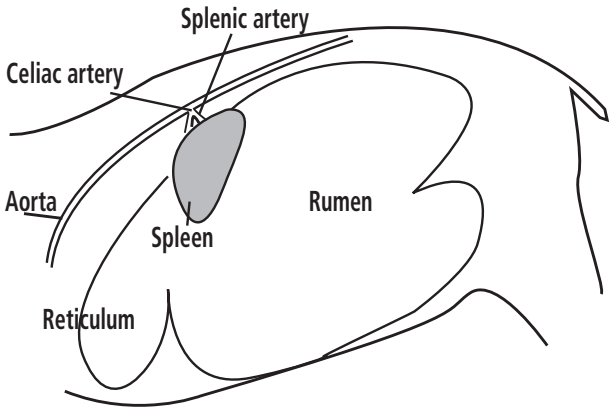

Fig. 2: Schematic of anatomical site

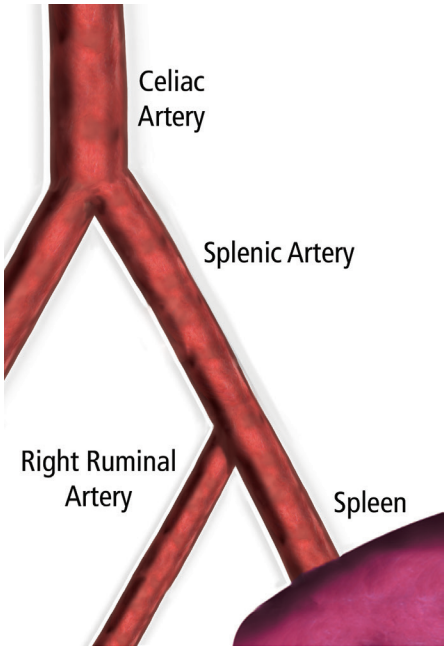

Fig. 3: Schematic of vessels

ACKNOWLEDGEMENT

Dr. Alan Dobson, Department of Physiology, NYS College of Veterinary Medicine, Cornell University, Ithaca, NY 14853

REFERENCES

Barnes RJ, Comline RS, Dobson A, Drost CJ, "Further Analysis of the Timecourse of the Changes in Blood Flow in Response to Feeding in the Ruminoticulum of the Sheep," International Union of Physiologists Society Satellite Conference on "Comparative Aspects of the Physiology of Digestion in Ruminants," Physiology Department Veterinary College, Univer ity of Sydney, Australia.

Barnes RJ, Comline RS, Dobson A, Drost CJ, "An Implantable Transit-Time Ultrasonic Blood Flow Meter," J Physiol 1983; 35: 2-3P.

Sheep Uterine Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Uterine artery
Species:	Sheep (ewe)
Weight:	40 kg
Duration:	Chronic - 15 days
Vessel Diameter:	4 mm

PROBE

Size:	4 mm (side exit)
Reflector:	L with sliding cover
Connector:	10 pin
Cable Length:	60 cm
Catalog #:	MC-4PSS-LS-WC60-CRS10-GC

FLOWMETER

TS420 Perivascular Module

Application

Uterine blood flow is used extensively in pregnancy research. Some investigators use blood flow in combination with arterial and venous sampling catheters to estimate the uptake of particular metabolites. Others use uterine blood flow in combination with pressure to monitor pharmaceutically induced changes in vascular resistance.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place anesthetized ewe in dorsal recumbancy and make a ventral paramedian incision from the umbilicus to a point 2 cm cranial to the udder. The skin incision is made 1 cm off midline to avoid the median subcutaneous vein. Retract the skin and associated vascular structures and continue the incision through midline of the abdominal wall. Locate the broad ligament and uterine artery lateral to the pregnant horn and follow the uterine artery down to the body of the uterus.

Dissect free a segment of the artery lateral to the body of the uterus and place the Probe around the artery. Close the slide and tighten the screw. Stable flow readings in the chronic implant occur much sooner when the Probe is firmly secured around the vessel. In this particular site, there is substantial loose connective tissue that can be used to secure and bury the Probe.

Flow Ranges Observed

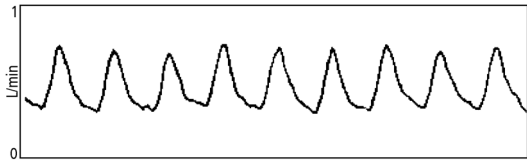

Fig. 1: Instantaneous flow ranges from 350 ml/min to 750 ml/min.

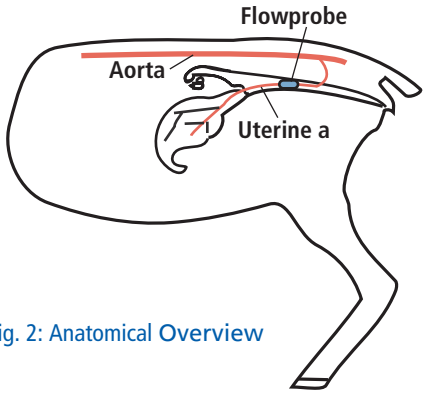

Fig. 2: Anatomical Overview

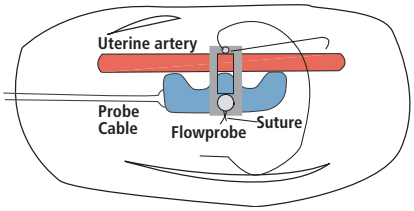

Fig. 3: Suturing the Probe to the vessel.

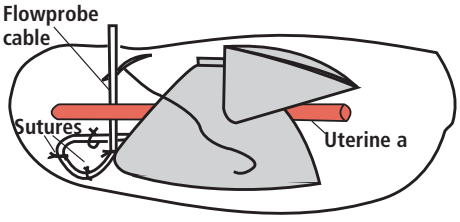

Fig. 4: Covering for the Probe.

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Sheep Uterine Artery: Chronic Blood Flow Measurement Cont.

Place a suture through the bracket hole and connective tissue as shown in Fig 3. Next, cover the Probe with loose tissue and suture as shown in Fig 4. Other flaps can be pulled over the Probe and sutured to the first flap. Also suture a loop of the cable to the connective tissue for strain relief.

Use a trocar to puncture the abdominal wall in the paralumbar fossa. Enlarge the incision by scalpel to allow passage of Probe cable.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices

ACKNOWLEDGEMENT

Sue Nobrega, Ramona Slepetis and Dr. Alan Bell, Dept. of Animal Science, Cornell University, Ithaca, NY

REFERENCES

Barnes RJ, Comline RS, Dobson A, Drost CJ, "An implantable Transit-Time Ultrasonic Blood Flow Meter", J Physiol 1983; 35: 2-3P.

Akagi K, Endo C, Saito J, Onodera M, Tanigwara S, Okamura K, Yajima A, Sato A. "Ultrasonic Transit-Time Measurement of Blood Flow in the Animal Chronic Preparation Model," Jpn. J. Med. Ultrasonics 1987; 14(2): 26-32.

Fetal Sheep Carotid Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Carotid
Species:	Fetal Sheep
Stage of Gestation:	118-140 days
Duration:	Chronic, 21 days
Vessel Diameter:	2 - 3 mm

PROBE

Size:	3 mm (side exit)
Reflector:	L with sliding cover
Connector:	4-pin
Cable Length:	1 m
Catalog #:	MC-3PSS-LS-WC100-CM4B-GC

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

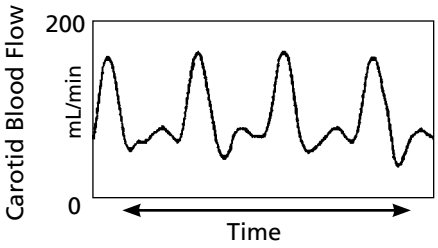

Fig. 1: Mean carotid artery blood flow in 132-day gestation lambs was 80 ml/min (range: 53-117 ml/min in 6 fetuses); in 138-day gestation lambs was 77 ml/min, (range: 49-103 ml/min in 5 fetuses).

FETAL LAMB: 140-DAY GESTATION		
SITE	**MEAN BLOOD FLOW**	**SAMPLING RATE**
Right carotid	66 ml/min	10Hz
Left carotid	63 ml/min	10Hz

Application

Carotid arterial blood flow has been used in pregnancy research. We used blood flow registration from both carotid arteries in combination with other fetal registrations (e.g. electro cortico gram, electro cardiogram and blood gas measurements).

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place anesthetized sheep in dorsal recumbency and make a ventral paramedian incision from the umbilicus to a point 2 cm cranial to the udder. The skin incision is made 1 to 2 cm off midline to avoid the median subcutaneous vein. Retract the skin and associated vascular structures and continue the incision through the midline of the abdominal wall.

Use a trocar to puncture the abdominal wall of the paralumbar fossa. Pass the Probe and cable through the trocar into the abdomen towards the uterus.

Identify and exteriorize the uterine horn containing the fetus. Palpate the fetus to identify the orientation and make a traverse incision in the uterus to allow exteriorization of the fetal head and neck. Once the fetus is exposed, palpate the trachea and make a median incision below the larynx. Expose the carotid artery over 3 cm. Make a pocket around the carotid artery in which the Probe fits in such a way that the Probe and cable parallel the carotid artery. Make a small paramedian skin incision above the first rib, pass the Probe and cable subcutaneous toward the pocket. Lift the carotid artery and pass the reflector bracket of the Probe under the artery. Close and secure the slide, drop a blood clot (maternal blood) around the bracket and slide, and suture the adjacent tissue (gl. thyreoidea and m. sternocleidomastoideus) over the Probe. Make sure that the fetal head and neck can be moved without moving the Probe.

Fetal Sheep Carotid Artery: Chronic Blood Flow Measurement Cont.

Secure the cable when necessary in a parallel position to the carotid artery. Close the fetal skin with 2-0 simple continuous sutures. Secure the Probe cable to the fetal skin with a 2-0 simple interrupted suture near the skin incision above the first ribbon.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Suture the cable to the skin, near the exit site. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

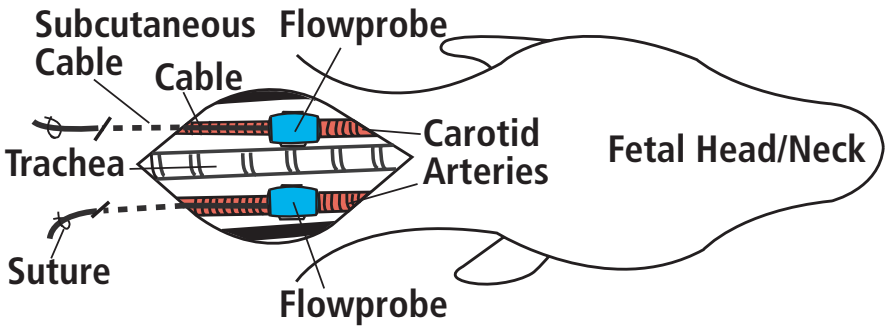

Fig. 2: Schematic of anatomical site and flowprobe placement

ACKNOWLEDGEMENT

A. Carrin M. Dassel[1], Jan M. Elstrodt[2], Bouke R. Woodstra[1], Prof. Dr. Jan G. AArnoudse[1], University of Groningen, Dept. of Obstetrics and Gynaecology[1], Oostersingel 59, 9713 GL, Groningen, The Netherlands, Animal Laboratory[2], A. Deusinglaan 50, 9713 AZ Groningen, The Netherlands.

Fetal Sheep Pulmonary Artery: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Pulmonary artery
Species:	Fetal Sheep
Stage of Gestation:	110 days
Duration:	Chronic, 30 days
Vessel Diameter:	6 mm

PROBE

Size:	6 mm (back exit)
Reflector:	L with sliding cover
Connector:	10-pin
Cable Length:	60 cm
Catalog #:	MC-6PSB-LS-WC60-CRS10-GC

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

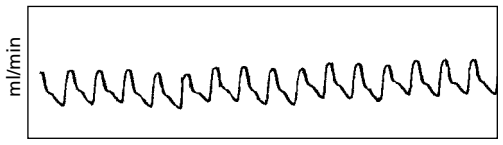

Fig. 1: Fetal sheep: 110 day gestation. Mean blood flow in the left pulmonary artery was 10 ml/min.

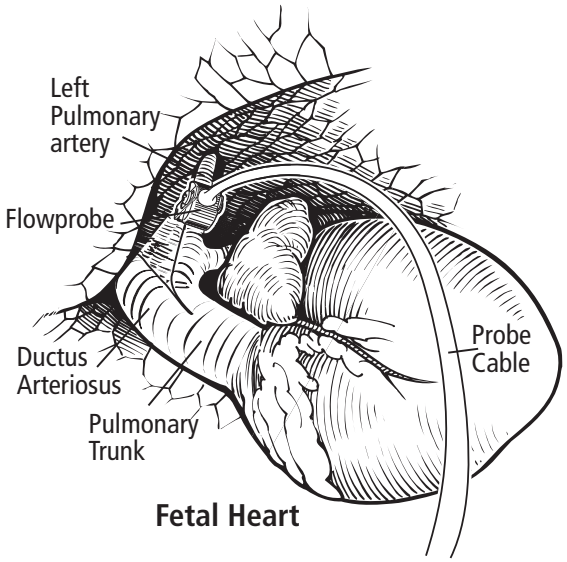

Fig. 2: Schematic of Probe placement on fetal heart.

Application

Blood flow in the pulmonary artery is used extensively in pregnancy research. Some investigators use blood flow in combination with pressure to measure changes in vascular resistance induced by pharmaceutical agents. Others look for diurnal patterns associated with parturition.

Surgical Approach

For a complete description of this surgery, please consult the publication by Rudolph et al., 1980 listed as one of the references at the end of this document.

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place anesthetized sheep in dorsal recumbency and make a ventral paramedian incision from the umbilicus to a point 2 cm cranial to the udder. The skin incision is made 1 cm off midline to avoid the median subcutaneous vein. Retract the skin and associated vascular structures and continue the incision through midline of the abdominal wall. Identify and exteriorize the umbilical horn containing the fetus. Palpate the fetus to identify the orientation and to locate the head and forelimbs.

Make a transverse incision in the uterus to allow access to the surgical site over the left upper thorax. Once the fetus is exposed pull the forelimb cranially and incise the skin and brachial muscles over the third intercostal space.

Fetal Sheep Pulmonary Artery: Chronic Blood Flow Measurement Cont

Carefully place a small hemostat around each adjacent rib and pass a #1 silk suture around each rib. These sutures can be used to lift the ribs so that the intercostal muscles and parietal pleura may be incised without damaging the underlying lung or heart. An infant size Finochietto rib-spreader may be used for retraction. Lift the pericardium, incise it from the pulmonary valve to the vagal nerve, place a #4-0 silk suture in the cranial edge of the pericardium and retract it. Using blunt dissection, carefully establish a plane of dissection between the ductus arteriosus and the pulmonary artery; it is may be necessary to cauterize small vessels in this area. Pass dissecting forceps behind the left pulmonary artery and pass two segments of 0.050" OD polyvinyl tubing around it.

Lift the left pulmonary artery with tubing segments and pass the reflector bracket of the Probe under the artery. Close and secure the slide and suture the Probe to adjacent tissue. Install a chest drainage tube and pass the cable out one end of the incision. Appose the ribs with a #1 silk suture. Close the muscle and the fetal skin in separate layers with 2-0 simple continuous sutures. Secure the Probe cable to fetal skin with a 2-0 simple interrupted suture. Close the uterus with a continuous Cushing pattern oversewn with a continuous Lembert, the Probe cable is exteriorized through this incision. Extend the Lembert pattern slightly to oversew the cable for 2 cm. Use a trocar to puncture the abdominal wall in the paralumbar fossa. Enlarge the incision by scalpel to allow passage of Probe connector.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Suture the cable to the skin, near the exit site. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

ACKNOWLEDGEMENT

Christine Roman and Dr. Abraham Rudolph, University of California, Dept. of Pediatrics, 1403 Health Sciences East Tower, San Francisco, CA

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Fetal Sheep Umbilical Artery (Dorsal Approach): Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Umbilical artery
Species:	Fetal Sheep
Stage of Gestation:	124 days
Duration:	Chronic, 15 days
Vessel Diameter:	4 mm

PROBE

Size:	4 mm (side exit)
Reflector:	L with sliding cover
Connector:	4-pin
Cable Length:	60 cm
Catalog #:	MC-4PSS-LS-WC60-CM4S-GC

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

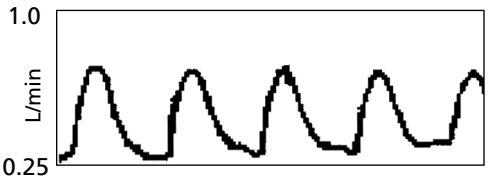

Fig. 1: Fetal sheep: 124 day gestation. Instantaneous blood flow was 400 ml/min to 900 ml/min. Mean flow was 620 ml/min.

Application

Umbilical arterial blood flow is used extensively in pregnancy research. Some investigators use blood flow in combination with pressure to measure changes in vascular resistance induced by pharmaceutical agents. Others look for diurnal patterns associated with parturition.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place anesthetized sheep in dorsal recumbency and make a ventral paramedian incision from the umbilicus to a point 2 cm cranial to the udder. The skin incision is made 1 cm off midline to avoid the median subcutaneous vein. Retract the skin and associated vascular structures and continue the incision through midline of the abdominal wall. Identify and exteriorize the umbilical horn containing the fetus. Palpate the fetus to identify the orientation and to locate the sacral crest. The ideal orientation is with the head of the fetus cranially located with respect to ewe and the dorsum of the fetus along midline incision.

Make a transverse incision in the uterus to allow access to the surgical site cranial to the fetal sacral crest. Once the fetus is exposed make a longitudinal skin incision just cranial to the sacral crest and slightly left of the spine. Use electro-cautery to incise through the epaxial muscles until the aorta is accessible. Take care not to damage the vena cava situated to the right of the aorta.
Preposition the slide so that the bracket hole is near the body of the Probe. Identify the umbilical artery and position the Probe as shown in Fig. 2. Close and secure the slide and suture the Probe to epaxial muscle taking care not to damage the adjacent vena cava. Close the epaxial musculature and the fetal skin in separate layers with 2-0 simple continuous sutures. Secure the Probe cable to fetal skin with a 2-0 simple interrupted suture.

Fetal Sheep Umbilical Artery (Dorsal Approach): Chronic Blood Flow Measurement Cont.

Close the uterus with a continuous Cushing pattern oversewn with a continuous Lembert, the Probe cable is exteriorized through this incision. Extend the Lembert pattern slightly to oversew the cable for 2 cm. Use a trocar to puncture the abdominal wall in the paralumbar fossa. Enlarge the incision by scalpel to allow passage of Probe connector.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Suture the cable to the skin, near the exit site. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

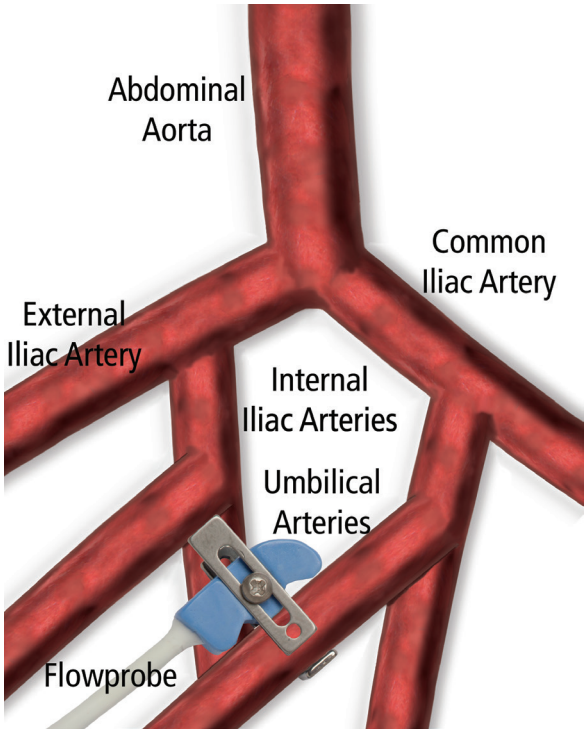

Fig. 2: Flowprobe on umbilical artery .

ACKNOWLEDGEMENT

Dr. Xiu-Yiing Ding, Drew Sadowsky and Dr. Peter Nathanielsz, Dept. of Physiology, Laboratory of Pregnancy and Newborn Research, NYS College of Veterinary Medicine, Cornell University, Ithaca, NY 14853.

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Fetal Sheep Umbilical Artery (Ventral Approach): Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Paired umbilical arteries
Species:	Fetal Sheep
State of Gestation:	109-120 days
Duration:	Chronic, 5 days
Vessel Diameter:	4 mm

PROBE

Size:	4 mm (side exit)
Reflector:	J
Connector	10-pin
Cable Length:	60 cm
Catalog #:	MC-4PSS-JN-WC60-CRA10-GC

FLOWMETER

TS420 Perivascular Module

Flow Ranges Observed

Umbilical flow was 210 ml/min/kg fetal weight in two fetuses and 105 ml/min/kg in one fetus.

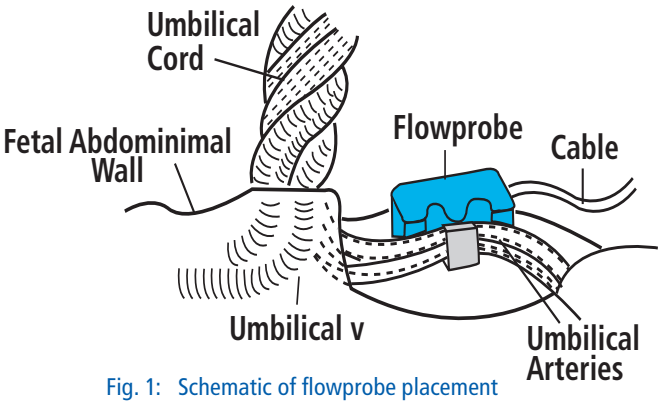

Fig. 1: Schematic of flowprobe placement

Application

Umbilical arterial blood flow is used extensively in pregnancy research. Some investigators use blood flow in combination with pressure to measure changes in vascular resistance induced by pharmaceutical agents. Others look for diurnal patterns associated with parturition.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

Place anesthetized sheep in dorsal recumbency and make a ventral paramedian incision from the umbilicus to a point 2 cm cranial to the udder. The skin incision is made 1 cm off midline to avoid the median subcutaneous vein. Retract the skin and associated vascular structures and continue the incision through midline of the abdominal wall. Identify and exteriorize the uterine horn containing the fetus. Palpate the fetus to identify the orientation and make a transverse incision in the uterus to allow exteriorization of the fetus. Once the fetus is exposed make a midline skin incision just caudal to the umbilical cord to expose the paired arteries. Place the J bracket around the paired arteries and suture the Probe in place. Close the abdominal musculature and the fetal skin in separate layers with 2-0 simple continuous sutures. Secure the Probe cable to fetal skin with a 2-0 simple interrupted suture.

Close the uterus with a continuous Cushing pattern oversewn with a continuous Lembert, the Probe cable is exteriorized through this incision. Extend the Lembert pattern slightly to oversew the cable for 2 cm. Pass the Probe cable through the abdominal wall.

Fetal Sheep Umbilical Artery (Ventral Approach):Chronic Blood Flow Measurement Cont.

Close the incisions in layers, using appropriate suture and technique to each individual layer. Suture the cable to the skin, near the exit site. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

ACKNOWLEDGEMENT

Kozo Akagi, Chikara Endo, Junya Saito, Masayuki Onodera, Masami Kozu, Shingo Tanigawara, Kunihiro Okamura, and Akira Yajima, Department of Obstetrics and Gynecology, Tohoku University School of Medicine, Sendai, 980, Japan.

Akira Sato, Department of Obstetrics and Gynecology, Fukushima Medical College, Fukishma, 960, Japan.

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Fetal Llama Carotid & Femoral Arterial: Chronic Blood Flow Measurement

APPLICATION BASICS

Site:	Carotid & Femoral arteries
Species:	Llama fetus
Stage of gestation	60% - 70%
Weight:	40 kg
Duration:	Chronic
Vessel Diameters:	Carotid artery: 3 mm
	Femoral artery: 2 mm

PROBE

Size:	3(2) mm (side exit)
Reflector:	L with sliding cover
Connector:	4-pin
Cable Length:	1.5 m
Catalog #:	MC-3(2)PSS-LS-WC150-CM4S-GC
FLOWMETER	TS420 Perivascular Module

Flow Ranges Observed

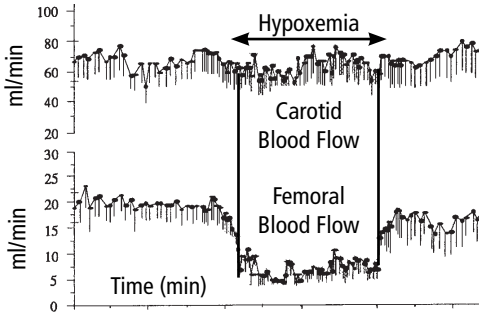

Fig. 1. Continuous carotid & femoral blood flow (means ± S.E.M.) in 5 fetal llamas at 60% - 70% of gestation during basal and hypoxemic conditions. Basal carotid and femoral blood flows were 65 ± 13.6 and 18 ± 3.4 ml/min respectively.

Application

Measurement of fetal carotid and femoral blood flows are used specifically as indices of a redistribution of the combined ventricular output during intra-uterine compromise, e.g. during acute hypoxemia (Fig. 1). Control of the fetal cardiovascular responses to stress involves neural responses, which are usually rapid in onset, and endocrine responses which develop more slowly. Greater information relating to the control of any specific cardiovascular response may thus be obtained, in the first instance, by determining its rate of onset. Continuous blood flow monitoring with Transonic Flowprobes permit such measurement to be studied in detail.

Surgical Approach

Aseptic technique, analgesia, anesthesia induction and maintenance, and other peri-operative regimens, such as prophylactic antibiotic administration, must be followed according to institutional guidelines and practices.

The llama is placed in the dorsal recumbency and a 10 cm ventral paramedian incision is made anterior to the mammary tissue from the umbilical scar. Sterile gauzes are used as abrasives to separate tissue from the peritoneum and the abdominal cavity is opened along the linea alba. A trochar is used to perforate the lateral wall of the abdominal cavity and the transducer lead is passed through the cannula. The cannula is then removed.

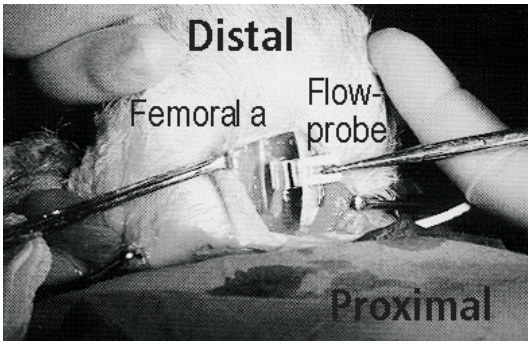

Fig 2: Flowprobe implantation around the femoral artery.

Fetal Llama Carotid & Femoral Arterial: Chronic Blood Flow Measurement Cont.

The fetus is palpated to identify orientation and a transverse uterine incision is made with an electrocautery to allow exteriorization of a fetal hindlimb. The femoral artery pulse is located within the cleft formed by the quadriceps and biceps femoris muscles and a 3 cm incisions made on the skin anterior to the abdomen and running parallel to the limb. The femoral artery is exposed by blunt dissection, taking care not to damage the femoral nerve, and the Probe reflector bracket is passed underneath it. The sliding cover is then closed and the Probe secured in place by tying four stitches through the Probe silicone flange into muscle tissue (Fig 2). The Probe cable is looped underneath the skin to prevent traction and the incision closed with a 2-0 silk simple continuous suture. A locking continuous suture is sewn over the edges of the uterine incision to aid hemostasis and prevent hemorrhage and the uterine wall closed with a continuous Cushing pattern.

A second uterotomy is made to allow exteriorization of the fetal head and neck. The trachea is palpated and a median 5 cm incision is made below the larynx. The carotid artery is located within the cleft formed by the sterno-hydroid and sterno-cleidomastoid muscles and exposed over 3 cm. The Flowprobe is passed underneath the artery and secured as for the femoral artery. The second uterine incision is closed as for the first one.

Close the abdominal wall and skin incisions in layers, using appropriate suture and technique to each individual layer. Follow postoperative care for incisions (including exit sites for cables or skin buttons for connectors when applicable), analgesia, sedation, and other necessary pharmacological regimens according to institutional guidelines and practices.

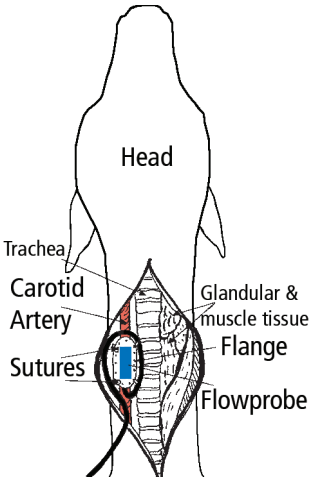

Fig. 3: Schematic of anatomical site

ACKNOWLEDGEMENT

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Appendix

Glossary

ACCURACY: the quality of adhering closely to a standard of correctness.

Absolute Accuracy: the accuracy of an instrument's measurement at most physiological flows; offset error is insignificant compared to slope error. The term absolute accuracy has therefore evolved as a synonym for the range of error resulting from an incorrect slope.
Relative Accuracy: the accuracy of the instrument: often a linear correction with a slope and offset. Relative accuracy is often known as linearity.

ACOUSTIC COUPLANT: Gel, such as Surgilube, H-R Jelly or NALCO 1181, used in the acoustic window of a Flowprobe during acute experiment to complete the acoustic pathway.

ACOUSTIC GEL: see Acoustic Couplant.

ACOUSTIC WINDOW/FIELD: the area defined by the pathway of the ultrasound beam between the transducers in the Flowprobe body and the acoustic reflector.

ACUTE: short-term use of a device as for intraoperative studies under anesthesia, typically less than one day. (Also see chronic & sub-acute.)

ANALOG OUTPUT SIGNAL: voltage output corresponding to the parameter measured by a device. The signal generated is calibrated by a scaling factor. The voltage range of Transonic transit-time Flowmeters is -5 to +5 volts DC with 1 volt equivalent to full scale of the Flowprobe used.

APPLICATIONS: documented uses for Transonic Flowmeters, Sensors and Probes.

BI-DIRECTIONAL FLOW: flow measured in positive and negative directions.

BI-DIRECTIONAL ILLUMINATION: with transit-time ultrasound Flowprobes, a tube or vessel is positioned between transducers which generate wide beams of ultrasound to fully illuminate the vessel or tube. The ultrasound beams alternately intersect the flowing liquid in upstream and downstream directions. The Flowmeter derives an accurate measure of the changes in "transit-time" (time it takes for the wave of ultrasound to travel from one transducer to the other) influenced by the motion of the liquid.

CALIBRATION: (often misused as a synonym for validation)
In Situ: adjustment or correction made to a measurement device for errors produced under actual conditions of use by comparing the measurement with a known standard.
In Vivo: adjustment or correction made to a measurement device during use in a "living body".

CHRONIC: long in duration. Long-term studies generally involving implanting a Flowprobe so that measurements can be made in the conscious animal. (Also see acute & sub-acute.)

CONFIDENCE FLOWPROBE®: a U-shaped, four-crystal Flowprobe with an Ultrafit Liner for measuring flows in vessels with turbulent flow profiles.

EPROM: (Acronym for "erasable programmable read only memory") programmed component that contains the identification and calibration information specific to each Flowprobe.

EXTENSION CABLE: cable, one end of which plugs into the connector of a Transonic Flowprobe and the other end of which plugs into the Flowmeter; generally 1, 2, or 3 Meters long.

EXTRACORPOREAL: measurements outside of a body.

FILTERS: in electronics, a circuit that only passes certain signals. For blood flow measurement, a low pass filter is often used to strip out high frequency noise, leaving only the biological components of interest.

FLANGE: a silicone rim or collar that can be cemented around PR-or PS-Series Probes to suture the Probe to surrounding tissue; used in coronary artery and umbilical artery applications.

FLOW: volume or velocity movement of a liquid (blood, saline, isotonic solutions) passing a given point in a given time (measured in L/min or ml/min).

FLOW VELOCITY PROFILE: the distribution of velocity across the vessel.

Glossary Cont.

FLOWMETER: a device for measuring velocity or volume of flow of liquids or gases passing a given point per unit of time. Specifically, with regard to Transonic Flowmeters, the box which houses the power supply and signal processing circuitry; a digital readout of the flow is displayed on the front panel.

FLOWMETRY: the monitoring or study of flow parameters.

FLOWPROBE: a device which measures flow. Transonic Perivascular Flowprobes contain the ultrasonic transducers for insonating vessels to measure volume flow of blood or other liquids.

FLOWSENSOR: a device which measures flow. Transonic Inline & Clamp-on Flowsensors measures the volume flow of a liquid passing through tubing by transit-time ultrasound technology.

GAIN: a linear factor in electronic circuitry used in a device as a multiplier after calibration. The sensitivity of a Probe is adjusted by changing the gain.

HZ: a cycle or repetition per second. In ultrasound: Transonic's specification for the frequency of the ultrasound from the Probe crystals is listed in Megahertz (MHz). For a 4PS Probe it is 2.4 MHz (2,400,000 cycles per second). In Data Acquisition: Sampling rates are reported in hertz; 100 Hz means 100 data points recorded per second.

KEY: EPROM separate from and specific to each Flowprobe that contains the identification and calibration information for Probes with 4-pin miniature connectors used in chronic applications. This programmed device plugs into a port on the Flowmeter.

NANOPROBES: Transonic 0.5 and 0.7 PS-Series Precision Flowprobes scaled to fit mouse anatomy; manufactured using nanofabrication techniques to phototech miniature structures to precision spec for accurate transducer alignment.

PERFUSION: the supplying of fluid to an organ or tissue. The passing of blood through the vasculature of an organ or tissue.

PERIVASCULAR: surrounding a blood or lymph vessel as in Transonic Perivascular Flowprobes for use on vessels.

PRECISION: the quality of repeatable recognition of minute changes in measuring a parameter. An instrument may be precise but inaccurate and vice versa.

PULSATILE FLOW: biological flows vary instantaneously throughout the cardiac cycle. The analog output can be filtered to give a pulsatile or mean flow signal.

RANGE: the set of numbers between the limits of the maximum and minimum values measurable.

REFLECTOR: stationary plate component of Transonic PR-& PS-Series Flowprobes. Each transducer alternately emits an ultrasound beam which is reflected from the stationary plate to a receiving transducer. The fixed distance of the reflective pathway is critical to transit-time ultrasound measurements and accurate measurement of volume flow.

RESOLUTION: represents the smallest detectable change in flow. Probe resolutions are generally specified at 0.1Hz filtering.

SAMPLING RATE: number of samples taken per unit of time. In digital signal processing (Nyquist theory) it is necessary to sample twice as fast as the highest frequency component.

SCALE: Factor used to calibrate a voltage signal. Transonic Flowprobes operate in either of two scales; low flow or normal flow scale determined by the range of flow under study.

SENSITIVITY: amount of voltage output per unit of parameter measured.

SENSITIVITY ERROR: error resulting from incorrect gain. Total error is the sum of sensitivity error and the offset error.

SIGNAL-TO-NOISE RATIO: the ratio of desired signal to undesired noise; often expressed in decibels, a logarithmic scale commonly used by engineers.

Glossary Cont.

SILICONE SHIELD: a silicone protective plate which encapsulates a U reflector on a PS-Series Flowprobe; used to maintain Probe orientation, cushion pulsatile vessels and retard fat ingress.

SILICONE WRAP: a reinforced mesh which is wrapped around a Transonic Flowprobe at an implant site to retard fat ingress and stabilize the Probe's position.

SUB-ACUTE: duration longer than acute, but not as long term as chronic; typically 8 hours to 3 days. In this context, subacute applications of Transonic ultrasound instruments are similar to acute applications where the implanted Flowprobe is not stabilized by fibrotic tissue ingrowth, and the ultrasound signal may yet be interrupted by the presence of air.

TIMED COLLECTION: a calibration technique combining a known volume with a measured time, as in the use of a beaker and stopwatch.

TRANSDUCER: a device that transforms a physical parameter into an electrical signal, as in a Transonic ultrasound Flowprobe; the ultrasound signal produced by the piezoelectric crystals is transformed and converted into an electrical signal proportional to volume flow.

TRANSIT-TIME: time it takes for a pulse of ultrasound to travel from one transducer to another.

ULTRASONIC: relating to energy waves similar to those of audible sound but of higher frequency (above 30,000 Hz)

ULTRASONIC COUPLANT: a material that propagates acoustical waves; for blood flow measurement, a material is chosen that mimics the acoustic characteristics of biological tissue.

ULTRASONIC SIGNAL COUPLING: a term used to describe the state of sound propagation between the transducer and tissue. Signal coupling is degraded by air bubbles and materials that do not conduct sound.

ULTRASONIC TRANSIT-TIME/ TRANSIT-TIME ULTRASOUND: a technology to measure volume flow of liquids by using wide-beam illumination; transducers pass ultrasonic signals back and forth, alternately intersecting a flowing liquid in upstream and downstream directions. The Transonic Flowmeter derives an accurate measure of the "transit-time" it took for the wave of ultrasound to travel from one transducer to the other. The difference between the upstream and downstream integrated transit-times is a measure of volume flow.

ULTRASOUND DILUTION: a technology which unites dilution and transit-time ultrasound to measure the changes that occur in the velocity of a liquid when diluted with isotonic saline; measures recirculation, access flow and cardiac output during hemodialysis.

VALIDATION: test to confirm calibration and accuracy of a measurement, usually by comparing to a known standard such as timed collection.

WAVEFORM: the record of a signal that varies over time. A blood flow signal usually varies periodically with the cardiac cycle.

WIDE-BEAM ILLUMINATION: the use of an ultrasonic beam wider than the vessel of interest. Wide-beam illumination is necessary for volume flow measurement with the transit-time ultrasound technique.

X-ILLUMINATION: ultrasonic illumination which fully illuminates the vessel or tube to provide a measure of volume flow by transit-time ultrasound. A vessel or tube is positioned between four transducers that generate wide beams of ultrasound that fully illuminate the vessel or tube. The ultrasonic beams alternately intersect the flowing liquid in upstream and downstream directions. The integrated difference between the two upstream and downstream transit-times is a measure of volume flow.

ZERO OFFSET DRIFT: zero offset change over time.

ZERO OFFSET: the measurement registered by the instrument under conditions of zero input. In blood flow, this is the Flowmeter reading when flow is known to be zero due to occlusion of the vessel or other means. A two point calibration can be performed by combining a zero offset determination with a timed collection.