TECHNICAL REPORT

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Evaluation of CPB devices relative to their capabilities of reducing the transmission of gaseous microemboli (GME) to a patient during cardiopulmonary bypass

Évaluation des dispositifs PCP relative à leurs capacités de réduire la transmission des micro-embolies gazeuses (MEG) à un patient durant un pontage cardiopulmonaire

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Contents

Foreword

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The committee responsible for this document is ISO/TC 150, *Implants for surgery*, Subcommittee SC 2, *Cardiovascular implants and extracorporeal systems*.

Introduction

Present-generation extracorporeal circuit devices are not designed to generate gas bubbles, as was the case with bubble oxygenators, as a function of their mechanism to achieve gas transfer. Gaseous microemboli (GME), while significantly reduced in current extracorporeal circuits, are still detectable.

The presence of GME in blood is not a normal condition and can trigger potentially adverse conditions as both a foreign surface and as a particle or embolus. Adverse systemic sequelae from GME may include activation of blood cells, immune responses, and blockage of blood vessels.

While attributing a causal relationship between GME and significant adverse clinical sequelae is not clear, laboratory equipment and methodology for testing extracorporeal devices on the bench top and are clinically available for use.

This document will review the current scientific literature on GME detection methodologies and their clinical relevance.

GME testing is currently being performed by companies and research groups. Both users and manufacturers will benefit from the creation of standardized terminology for use in this work.

Development of a consensus position on the clinical implications of GME and the capabilities and limitations of currently utilized monitoring equipment will also serve both users and manufacturers.

The currently available monitoring equipment will have a cost impact on all manufacturers and may burden small enterprises more so than existing larger companies. The equipment cost, however, is less expensive than equipment currently required to evaluate many of the extracorporeal devices such as blood gas analysers, cell counters or spectrometers. Independent investigators with such equipment and expertise are also an option.

Evaluation of CPB devices relative to their capabilities of reducing the transmission of gaseous microemboli (GME) to a patient during cardiopulmonary bypass

1 Scope

This document recommends acceptable methodology for conducting gaseous microemboli (GME) testing and discusses limitations of current test methods. Tests described in this document are limited to those conducted using an *in vitro* circulatory system.

This document is applicable to all devices intended for extracorporeal circulatory support during cardiopulmonary bypass (CPB). It outlines approaches currently used to assess the ability of CPB devices to handle GME.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at http://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

3.1
cardiopulmonary bypass
extracorporeal circuit used to support a subject's circulatory and gas exchange requirements when the heart and lungs are temporarily functionally excluded from normal circulation during cardiac surgery

3.2
gaseous microemboli
air bubbles present in circulating blood that are in the range 10 µm to 500 µm diameter

3.3
ultrasonic detector
device based on Doppler phenomenon (pulsed or continuous wave) that emits sound signals from a piezoelectric crystal that are reflected from moving blood

EXAMPLE 1 Transcranial Doppler, transesophageal echocardiography, or clamp-on sensors for extracorporeal tubing with the latter used for bench top *in vitro* testing.

EXAMPLE 2 Ultrasonic detectors are able to discriminate circulating particles from background blood flow, and detected reflections (or signals) can be analysed in real time to produce a display of approximate quantities and sizes during the sampling time frame.

3.4
whole blood
fluid used for bench-top studies involving gaseous microbubbles is anticoagulated whole blood

4 Abbreviated terms

CPB cardiopulmonary bypass

GME gaseous microemboli

5 Recommendations

5.1 General

This document addresses current state-of-the-art bench-top testing and is intended to provide guidance to those performing such tests so that reproducible results may be obtained to compare devices. Use of anticoagulated whole blood is noted to provide more relevant results when performing bench-top GME studies. This clause provides testing recommendations.

5.2 Materials and methods

5.2.1 The bench-top circuit should be described in sufficient detail so that an identical circuit can be assembled for additional testing by other parties.

5.2.2 The description of the circuit should include the following:

— physical components, including:

  — tubing dimensions (material, internal diameter, wall thickness, length);

  — types and dimensions of tubing connectors used;

  — manufacturer and model of detector;

  — number, specific location, and method of attachment of detector sensors in the test circuit;

  — other circuit components such as the device being evaluated;

  — type of pump used to circulate blood;

  — presence of a debubbling chamber (if used);

— conditions of the test, including temperature of test fluid, fluid flow rate, establishment of baseline conditions, site of injection of bubbles;

  — hematocrit (should be specified);

  — isotonic solution (shall be used for dilution);

  — anticoagulant used (should be specified);

— evidence of calibration of the bubble detector;

— method of introduction of bubbles into the test circuit (e.g. continuous injection vs. bolus injection), total volume over time of bubbles introduced and means of introduction (e.g. calibrated pump vs. hand injection);

— gas composition (should be room atmosphere only);

— reservoir level when using a hard shell (should be specified);

— volume of blood and the presence (when a soft bag venous reservoir is being tested) and the position of volume regulation mechanism (should be described).

5.2.3 The duration of the test, sampling schedule, and number of tests should be described.

5.3 Results and verification of test

5.3.1 Bubble counts according to the location of the detector sensors should be quantified in terms of sizes and numbers.

5.3.2 The total volume of gas may be reported based on calculations of sizes and numbers.

5.3.3 Results may be reported in numerical or graphical form.

5.3.4 As noted in 5.2.3 above, the number of tests performed under a given set of conditions must be reported with the results, and if the results represent mean values of several tests, this should be noted.

5.4 Components

Components that may be tested include, but are not limited to, one or a combination of the following:

5.4.1 Combination cardiotomy/venous reservoir

This component consists of a hard shell reservoir with multiple inlet connectors and internal chambers used to process either cardiotomy-suctioned blood or venous blood.

These components may contain gross filters and defoamers for removal of large bubbles and blood debris such as large clots or fat particles.

After processing both types of blood, a settling chamber collects the blood for removal by a pump and transmission through the gas exchange section of the oxygenator.

5.4.2 Standalone cardiotomy reservoir

This component is used for processing either cardiotomy-suctioned blood or vent blood.

After processing, blood typically drains by gravity into a larger reservoir and becomes part of the circulating blood.

Processed blood may be sequestered in the reservoir for additional processing by a cell salvage/wash unit.

5.4.3 Standalone venous reservoir, either hard shell or flexible bag type

These components only collect blood from the CPB venous drainage tubing.

5.4.4 Oxygenator with or without integral arterial filter

This component consists of multiple fine strands of hollow fibres containing flowing gas arranged in a configuration to promote mixing of venous blood near the fibre surfaces for gas exchange to take place.

A heat exchanger for circulation of temperature-controlled water most often is integral to the oxygenator.

An integral arterial filter may or may not be part of the oxygenator.

5.4.5 Standalone arterial filter

This component consists of a fine screen mesh fan-folded to provide sufficient surface area for flows used during CPB with an acceptable pressure drop.

