Detection of Fluorescence in Blood Using Fibre-optic Catheter

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Usage of photo-technology is limited in anaesthesia and intensive care field. Although an intravenous fibre-optic catheter has been clinically available, it is not utilised except for estimating oxy-haemoglobin fraction using absorbance spectrometry. Some molecules emit specific wavelength light, the fluorescence, when they are excited by light of higher energy or shorter wavelength. As the wavelength of the fluorescence is molecular specific and is different from that of incident light, fluorescence spectrometry has several advantages comparing with absorbance spectrometry. The purpose of this study was to develop techniques to detect fluorescence in blood.

Methods:

1. Optical instrument

The optical instrument was designed for the Abbott fibre-optic catheters to detect fluorescence of indocyanin green (ICG) in blood. The light source, a Xenon short arc lamp (HAMAMATSU Co, Japan) provides stable broadband light from 220 to 2000 nm. The light band is focused on 766 nm band pass filter. The filtered light is guided to a coupler that is specially designed for the optic module of the Abbott catheters and excites ICG. The coupler also receives the light emitted by blood and passed through the catheter. The 830nm band pass filter is placed on just after the coupler to select the fluorescence emitted by ICG. The intensity of the fluorescence is measured by a photodiode (S-6024, HAMAMATSU Co. Japan) and an amplifier (C-5460, HAMAMATSU Co. Japan).

2. In vitro study

We investigated influence of red blood cell count or haemoglobin concentration on the fluorescence intensity. Human blood was diluted by saline and adjusted to three haemoglobin concentrations, 15, 10 and 5 g/dl. Relationship between ICG concentration and the fluorescence intensity was studied in the three blood samples in a tube. The concentration of ICG was gradually increased up to 3 μg/ml.

3. In vivo study

Three New Zealand White rabbits, 3.2 – 4.5 kg weight, were anaesthetised with ketamine and diazepam, and breathed spontaneously. A 5.5 Fr Abbott fibre-optic catheter was inserted from right jugular vein. The tip of catheter was placed at three positions; superior vena cava, right atrium and inferior vena cava under X-ray fluoroscopy, and recorded 830 nm signal output at each position. At the position of the minimum noise 5 mg of ICG was injected in the right jugular vein.

Results:

The in vitro study showed that the relationship between ICG concentration and the fluorescence intensity was linear up to 3 μg/ml, and this relationship was almost same in the three blood samples of different haemoglobin concentrations. The in vivo study showed that the signal noise was minimum when the catheter tip was at the inferior vena cava all three rabbits. The 5 mg of ICG injected intravenously provided sufficient intensity of 830 nm fluorescence signal.

Discussion:

This is the first report that fluorescence in blood was detected with a clinical available fibre-optic catheter. This fluorescence spectrometry with fibre-optic catheter is expected to show advantages in several clinical settings. This technique may improve the accuracy of cardiac output estimation because thermodilution method potentially overestimates the value resulting from heat shift to surrounded tissue especially in low cardiac output state. Although non-invasive pulse dye densitometry (PDD) is clinically available and provides blood volume and ICG elimination constant,

the PDD does not work well unless peripheral arterial pulsation is sufficient. This technique possibly overcomes the weak point of the PDD and provides accurate values even in low blood circulation state. The fluorescence spectrometry is able to detect other intra-blood materials besides ICG, and has a possibility to be applied to various techniques.

Conclusions:

We could detect the fluorescence of ICG in blood using a clinical fibre-optic catheter. The intensity of the fluorescence was independent of haemoglobin concentration.