Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofSurgicalResearch.com

Investigation of blood coagulation effect of nonthermal multigas plasma jet *in vitro* and *in vivo*

Yudai Nomura, MD,[a] *Toshihiro Takamatsu, PhD,*[a,b,*] *Hiroaki Kawano,*[b] *Hidekazu Miyahara, PhD,*[b] *Akitoshi Okino, PhD,*[b] *Masaru Yoshida, MD, PhD,*[a,c,d] *and Takeshi Azuma, MD, PhD*[a]

[a] *Division of Gastroenterology, Department of Internal Medicine, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan*

[b] *Institute of Innovative Research, Tokyo Institute of Technology, Yokohama, Japan*

[c] *Division of Metabolomics Research, Department of Internal Related, Kobe University Graduate School of Medicine, Kobe, Hyogo, Japan*

[d] *AMED-CREST, AMED, Kobe, Hyogo, Japan*

ARTICLE INFO

Article history:
Received 17 February 2017
Received in revised form
17 May 2017
Accepted 16 June 2017

Keywords:
Blood coagulation
Hemostasis
Low temperature plasma
Cold plasma
Atmospheric pressure plasma
Multigas plasma

ABSTRACT

Background: Nonthermal atmospheric pressure plasma (NTAPP) has recently received attention as a novel tool in medicine. It is thought that plasma components yield plasma effects such as sterilization, blood coagulation, and wound healing. These effects are produced without thermal damage. We investigated the blood coagulation effect of NTAPP by using a multigas plasma jet.

Materials and methods: Multigas plasma jets can generate NTAPP by several gas species. In this study, argon, oxygen, helium, nitrogen, mock air, and carbon dioxide were used to generate NTAPP, and blood coagulation times were compared with each plasma-treated sample. The NTAPP blood coagulation effects on whole blood with four different anticoagulants were investigated. In addition, in this study, the effects of plasma treatment on porcine tissues and organs were investigated as *in vivo* experiment.

Results: A tendency to coagulate later with argon gas plasma than others was shown. There were no significant differences between oxygen, helium, nitrogen, mock air, and carbon dioxide. Whole blood with each anticoagulant demonstrated fast coagulation by NTAPP treatment. Fast control of the bleeding lesions on porcine stomach and liver by plasma treatment was observed, and no tissue damage due to the plasma treatment was detected by optical microscope.

Conclusions: These experiments suggest the potential of various gas NTAPPs as a novel medical device to control bleeding lesions.

© 2017 Elsevier Inc. All rights reserved.

Introduction

Gastrointestinal bleeding is a situation that we frequently encounter clinically and can be lethal. Some endoscopic treatments are employed for bleeding, that is, endoscopic clipping, injection therapy (absolute ethanol or hypertonic saline), high-frequency coagulation, and argon plasma coagulation (APC).[1-3] However, there are problems with each

*Corresponding author. Division of Gastroenterology, Department of Internal Medicine, Kobe University Graduate School of Medicine, 7-5-1 Kusunoki-cho, Chuo-ku, Kobe, Hyogo, Japan. Tel.: +81 78 382 5881; fax: +81 78 382 6309.
E-mail address: tplasma@med.kobe-u.ac.jp (T. Takamatsu).

0022-4804/$ – see front matter © 2017 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.jss.2017.06.055

of these therapies. Endoscopic clipping needs to hold a bleeding vessel precisely. Furthermore, it can be difficult to observe the target lesion in detail and to perform additional therapy after endoscopic clipping. Absolute ethanol injection therapy has tissue toxicity and high-frequency coagulation and APC lead to thermal damages to the treated tissue that can cause ulceration or perforation of the gastrointestinal wall. Nonthermal atmospheric pressure plasma (NTAPP) has recently received attention as a novel tool in medicine. Plasma is composed of several active species such as charged particles, electronically excited atoms and molecules, radicals, and ultraviolet photons.[4,5] It is thought that these generated components yield plasma effects such as sterilization,[6] blood coagulation,[7-10] and wound healing.[11-13] These effects are produced without thermal damage.[14]

Two different approaches are used for plasma treatment. One approach is called direct plasma—plasma is generated between an electrode covered by a dielectric material and the sample tissue forms the second electrode. Thus, in this approach, the sample tissue contacts the discharge directly, but it has a need to maintain a range for atmospheric discharge between the electrode and the sample. The NTAPP jet source offers another approach called indirect plasma—this can treat a distance of several millimeters by a gas flow delivering the plasma components.[15-17] After glow of NTAPP components can be seen during treatment, so it is easy for everyone to irradiate the target lesion without special training. Locations requiring hemostasis treatment during surgical or endoscopic operations have irregular surfaces as they are organic structures or lesions, and may also move due to breathing or pulsation in many cases. So it is considered that remote treatment by indirect plasma is more suitable for medical use.

In many previous studies, helium or argon was used for plasma generation. The effects and safety of NTAPP are still unclear. We used a multigas plasma jet that can generate NTAPP from several gas species. Our previous study showed that the kinds and amounts of active species vary by gas species. In addition, the effects of hydrophilization and sterilization changed significantly with gas species.[18] We determined to investigate the difference of the coagulation effect by gas species. Thus, in this study, the potential of NTAPP as a novel endoscopic device for blood coagulation without thermal and discharge damage was investigated *in vitro* and *in vivo*.

Materials and methods

Plasma source

The multigas plasma jet source[19-22] has a columnar body like a pen and is connected to an AC power supply (Plasma Concept Tokyo, Inc, Tokyo, Japan) of 16 kHz and 9 kV and a gas cylinder. Plasma is generated between a stick electrode at the center of the body and a cylindrical electrode around the stick electrode. The generated plasma components are delivered by gas flow through a hole (2 mm diameter). The multigas plasma jet source can generate atmospheric plasma of various gas species including argon, oxygen, helium, nitrogen, mock air (N_2:O_2 = 4:1), and carbon dioxide at low gas temperatures (<57°C).[23] The generated plasma has a different character depending on the gas species.

Coagulation effect of NTAPP on human blood

Human blood was observed after treatment with NTAPP. Blood was drawn from healthy adult volunteers who had no history of hematologic disease and did not recently take medicine. Experiments using human blood were approved by the research ethics committee of Kobe University Hospital (No. 160110).

The experiments were performed as follows. Blood with anticoagulants, in a volume of 10 μL, was set on an adjustable platform and the multigas plasma jet was fixed at 7 mm from the jet hole to sample. The gas flow was set 5 L/min as shown in Fig. 1.

First, the blood coagulation time was compared for each plasma treated sample. Blood samples with 3.2% sodium citrate (VENOJECT II VP-CA053K; Terumo Corporation, Tokyo, Japan), volume 10 μL, were treated by argon, oxygen, helium,

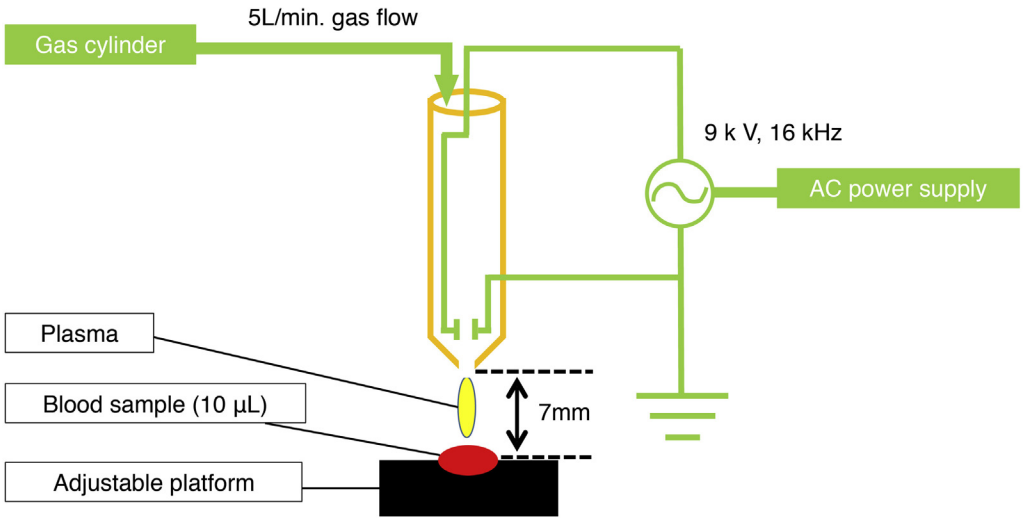

Fig. 1 – Multigas plasma jet for blood coagulation setup. (Color version of figure is available online.)

Download English Version:

https://daneshyari.com/en/article/8835876

Download Persian Version:

https://daneshyari.com/article/8835876

Daneshyari.com