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ORIGINAL ARTICLE

TRANSECTION OF METAL STENTS USING ARGON PLASMA COAGULATION

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Background: Placement of self-expandable metallic stents has become the preferred palliative treatment for patients with unresectable malignant biliary obstruction. Metallic stents provide longer patency compared with plastic stents. Distal malposition or migration of metallic stents sometimes occurs, but it is often difficult to remove them. We evaluated the efficacy and safety of argon plasma coagulation (APC), and the optimum conditions for cutting metallic stents (Wallstent).
Methods: We wrapped porcine small intestines around a metallic Wallstent with and without silicon lining membrane (Permulume®), leaving the distal portion unwrapped to resemble the protrusion of the biliary metallic stent from the ampulla of Vater. APC irradiation was applied to the metallic stent at 1 cm from the edge of the wrapped small intestine at 30, 60 and 99 watts (W) for 3 or 6 s.
Results: Metallic Wallstent with the silicone-based membrane Permalume® was cut at 30 W power, whereas more than 60 W power was required to cut the bare metallic wire. The irradiation of APC (flow rate at 2.0 L/min) at 30 W to the covered metallic stent transected the metallic mesh stent not only under dry but also under wet conditions (moisturized stent). Irradiation of APC caused no gross damage to the small intestines irrespective of the power applied and duration of irradiation.
Conclusions: Our results suggest that APC is efficacious and safe for endoscopic sectioning of wire mesh stents at low power (30 W) without gross damage to the surrounding pancreaticobiliary tissues.

Key words: argon plasma coagulation, biliary obstruction, metallic stent, transection.

INTRODUCTION

Self-expandable metallic stents are useful for palliative treatment of unresectable malignant biliary obstruction.[1] Endoscopic stent placement is less invasive than surgery and rapidly effective,[2] and improves the general condition of patients. Metallic stents have longer duration of patency compared with plastic stents.[3,4] However, distal migration is one of the common complications after insertion of a covered metallic stent.[5] Migration disturbs biliary drainage[6,7] and distal impaction of a malpositioned metallic stent can cause a bleeding duodenal ulcer. Stent repositioning or removal is difficult in cases of misplacement, occlusion or migration.[8] Furthermore, endoscopic extraction by careful pull out could potentially cause significant injury of the duodenal mucosa and the bile duct, and damage the working channel of the endoscopy itself.[9] Neodymium-yttrium aluminum garnet laser (Nd:YAG) has been used to treat malpositioned biliary metallic stents.[10,11] However, it is not a commonly used technique and sometimes causes tissue injury and perforation.[10] Argon plasma coagulation (APC) has been used for more than 10 years in open surgery, laparoscopy and thoracoscopy, especially for hemostasis of large surface bleeding and tissue ablation.[12] It is a non-contact method of delivering electrocautery current to tissues via an ionized argon gas stream (argon plasma). Recently, APC has also been used to trim covered and uncovered Elgiloy® stents (Elgiloy Specialty Metals, Elgin, IL, USA) and nitinol stents in selected patients and animal experiments.[7,9,13–16] In the present study, we evaluated the safety, efficacy and the optimum conditions of APC for transecting the metallic Wallstent *in vitro*.

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METHODS

In the present *in vitro* study, we used porcine small intestine and used uncovered (bare stents) and covered metallic Wallstent (Boston Scientific Corporation, Natick, MA, USA) with poly dimethyl siloxane membrane (Permalume®; Boston Scientific Corporation) (Fig. 1). Plasma argon fulguration (ERBE ICC200; ERBE Elektromedezin, Tübringen, Germany, and ConMed, Utica, NY, USA) was performed using flexible probes similar to the devices used for coagulation (2.3 mm diameter, 300 cm length). The power was set at 30, 60 and 99 watts (W) for 3 or 6 s, and the argon flow at 2.0 L/min according to the recommendation by Grund *et al.*,[17] for the treatment of upper gastrointestinal tract lesions. As it was difficult to create a model of the bile duct or to perform the study using the bile duct, we used porcine small intestine to simulate the bile duct. We wrapped the small intestine around the metallic stent, leaving approximately 2 cm of the distal end of the stent unwrapped to resemble the protrusion of the metallic stent from the

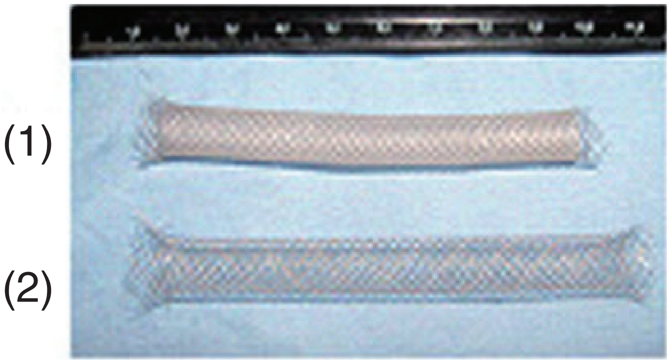

Fig. 1. Uncovered metallic Wallstent[1] and the covered metallic Wallstent with the silicone-based membrane Permalume®.[2]

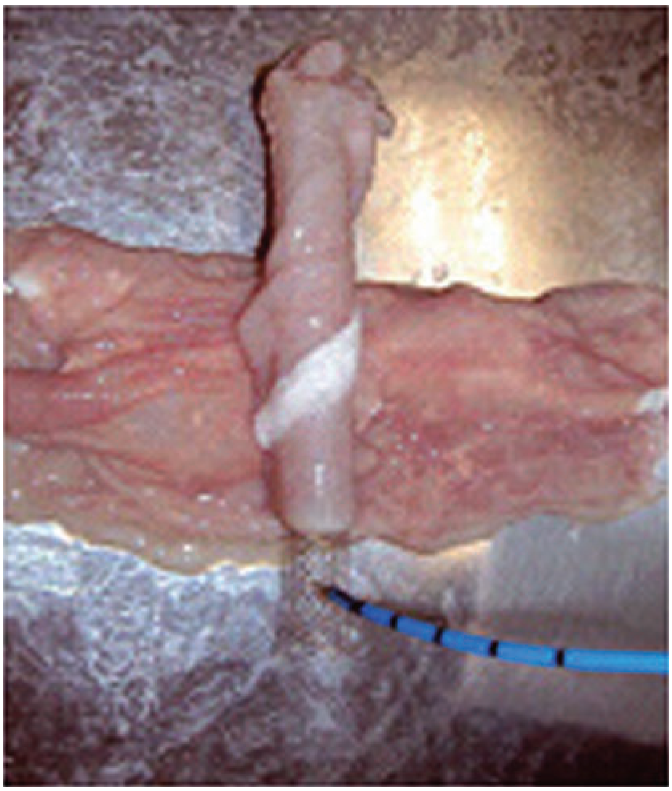

Fig. 2. *In vitro* experimental model. Porcine small intestine was wrapped around the metallic stent to simulate the bile duct, leaving approximately 2 cm of the distal end of the stent unwrapped to resemble the protrusion of the metallic stent from the ampulla of Vater. Argon plasma coagulation was applied in close proximity to the edge of the wrapped porcine small intestine (approximately 1 cm).

ampulla of Vater (Fig. 2). APC was applied in close proximity to the edge of the wrapped porcine small intestine (approximately 1 cm).

RESULTS

Exposure of the uncovered metallic Wallstent at 1 cm from the edge of the wrapped small intestine to the irradiation power of 30, 60 or 99 W for 3 s resulted in transection of the metallic mesh, creating holes of 1, 2 and 4 mm in diameter, respectively (Fig. 3a–c). When the duration of irradiation at 30, 60 or 99 W power was increased to 6 s, the diameters of the holes were 1, 5 and 4 mm, respectively (Fig. 3d–f). Application of APC caused no gross damage to the wrapped small intestine, irrespective of the power applied and duration of laser irradiation.

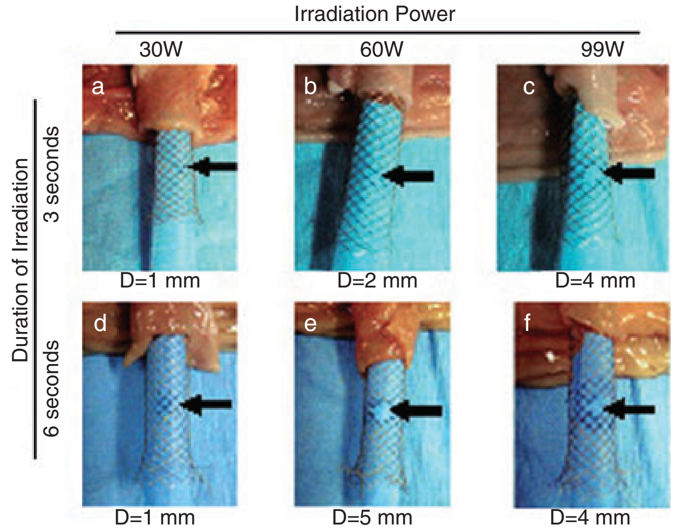

Fig. 3. Effects of the irradiation power and duration of argon plasma coagulation (APC) on transection of the uncovered metallic Wallstent. Uncovered metallic Wallstents were exposed to irradiation power of 30, 60 or 99 W for 3 or 6 s. Arrows indicate the holes created by APC. D, diameter of the hole.

Exposure of the covered metallic Wallstent with internal Permalume® lining membrane to 30 W power for 3 s created holes of 3 mm diameter in the stent and 9 mm diameter thermal degeneration of the Permalume® covering membrane (Fig. 4a). An application of 60 W for 3 s increased the diameter of the hole in the metallic mesh (6 mm), and damaged a large area of the Permalume® membrane (Fig. 4b). However, there was no gross injury to the small intestine under these conditions.

Whereas the above *in vitro* studies on the uncovered and covered metallic Wallstent were conducted under dry conditions, it is wet in the gastrointestinal tract when used for the treatment of patients *in vivo*. Therefore, we repeated the above studies on the covered metallic stents after moisturizing with distilled water. Exposure of the moisturized covered metallic Wallstent to irradiation at 30 and 60 W power for 3 s resulted in smaller holes of 4 and 3 mm in diameter, respectively, in the metallic stents (Fig. 4c,d).

DISCUSSION

The Wallstent is constructed of a superalloy called Elgiloy® (Elgiloy Specialty Metals), which is constructed of cobalt and has been shown to have high strength, ductility and fatigue resistance. The covered Wallstent has a proprietary silicone-based membrane Permalume® to prevent tumor ingrowth. However, this membrane may increase the risk of stent migration.[18] Malpositioned or migrated stents may cause serious complications such as duodenal ulcer and bleeding or

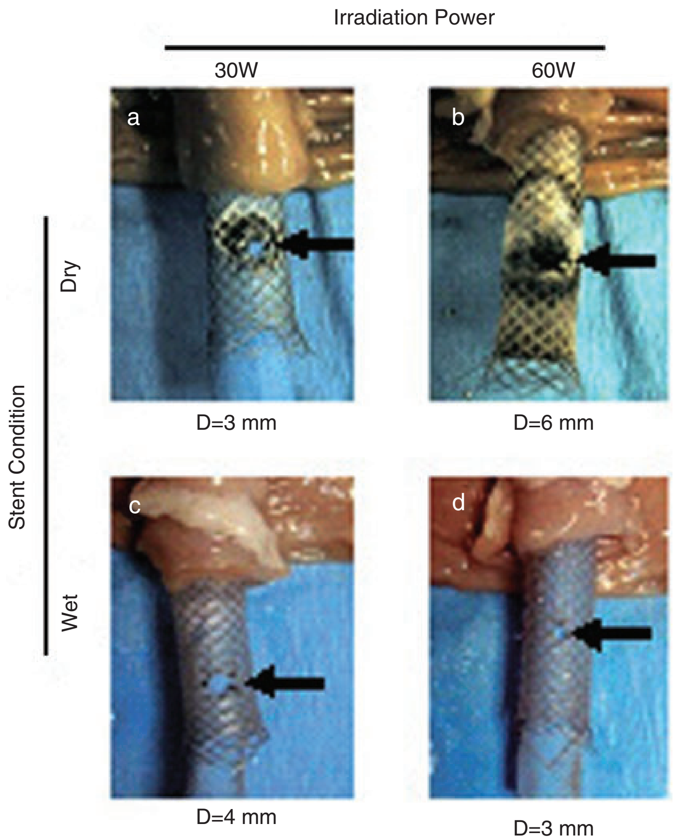

Fig. 4. Effect of the stent condition, dry or wet, on the transection of the covered metallic Wallstent. The covered metallic Wallstents under (a,b) dry and (c,d) wet conditions were exposed to irradiation power of 30 or 60 W for 3 s. Wet condition was achieved by moisturizing the covered metallic stent with distilled water. Arrows indicate the holes created by APC. D, diameter of the hole.

even perforation by the free edge of the intraduodenal protruded portion of the stent, and occasionally make transpapillary access difficult.[7]

Several methods to remove or to trim the biliary metallic stent have been reported.[7,9–11,13–16] Extraction techniques have a risk of mechanical injury of the duodenal mucosa and damage to the endoscope.[9] Recent studies have revealed that APC application for trimming and cutting metallic stents is effective and clinically safe.[7,9,13–16]

APC is a non-contact method of delivering electrocautery currents to tissue via an ionized argon gas stream (argon plasma). Irradiation by using APC is distributed laterally and radially, and its effect is transmitted easily to non-coagulated and bleeding tissue areas, which have lower electrical resistance. Based on these properties, the thermal effect of APC on the tissue is low with a limited depth of tissue coagulation (2–3 mm).[13,19] APC has been used for hemostasis in cases of open[20] and laparoscopic surgery[21] and gastrointestinal bleeding, and for destruction or ablation of tumors.[9,22] APC might cause thermal damage to the epithelial wall of the bile duct.[16]

In the present study, application of APC at 30 W power was ineffective in cutting the uncovered metallic Wallstent and the efficacy was not improved by prolongation of the duration of irradiation. Interestingly, however, application of APC at 30 W power effectively cut the metallic Wallstent with the internal Permalume® membrane. Thus, the covered Wallstent with an internal lining membrane can be effectively cut by APC even at 30 W power, whereas that of the uncovered stent requires repeated irradiation with power set at more than 60 W. In the gastrointestinal tract, APC is commonly used with the argon gas flow rate at 1–2 L/min, and the power at 30–80 W.[12] Although previous studies used APC at 70–80 W power, they were unable to cut the covered metallic stent with an internal lining membrane.[7,9,13,14] Vanbiervliet *et al.* failed to trim a Permalume®-covered Elgiloy® stent by APC in an *in vitro* study, and speculated of a possibility that the covered polyurethane prevented successful trimming of the stent.[14] In contrast, however, the present *in vitro* study clearly demonstrated that the Permalume®-coated segments of the stent can be cut by APC at lower power (30 W) than that required for cutting bare metallic stents (more than 60 W). This may be due to the different types of wire that make up the stents; the uncovered Wallstent is made of Elgiloy® and tungsten wire, whereas the covered Wallstent is made of Elgiloy® and tantalum wire.

Application of APC to the covered and uncovered metallic Wallstent caused no gross damage to the wrapped porcine intestine, suggesting a possibility that the energy delivered to the stent is not directly transmitted to the papillary tissue on the biliary metallic stents. However, in the absence of histological data, there is a persistent concern that high temperature generated by APC and rapid heat conduction by the metallic stent could result in undetected thermal injury to the underlying biliary tissue and/or the surrounding pancreaticobiliary orifice. Indeed, Chen *et al.* have demonstrated in anesthetized pigs that APC can cause biliary epithelial injury secondary to conduction of heat and electrical energy, although the cellular damage was superficial, extending to a maximum depth of 0.1 mm with only rare foci involving subepithelial connective tissue, and only confined to the vicinity (within 2 mm) of the bile duct orifice.[16] However, the energy settings selected for their study were much higher than that used in the present study (70 W *vs* 30 W).[16] In addition, as metallic stents have lower electrical resistance than silicone and body tissues, such as the papillary tissues, argon plasma by APC flows to the metallic mesh rather than to surrounding tissues. It is conceivable, therefore, that 30 W power does not cause severe thermal injury to biliary tissue. In summary, the present *in vitro* study suggests that APC is an effective and probably safe procedure for cutting misplaced, occluded or migrated metallic Wallstents with minimal bile duct injury.

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