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Preserving the Integrity of Oesophageal Stents with Laser Therapy and Argon Plasma Coagulation: An In Vitro Study

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Abstract. Thermal lasers and argon plasma coagulation are widely used in the treatment of stent overgrowth in patients with advanced oesophageal malignancy. The aim of treatment is to achieve patency while avoiding damage to the prosthesis. This experimental study was designed to determine the power and duration of application that can be safely tolerated by four different types of oesophageal prostheses. Five stents were studied: wall stent; open metal mesh stent (uncovered Ultraflex); covered metal mesh stent (covered Ultraflex); Gianturco (Z-stent); Esophagocoil. Nd-YAG Laser, GaAlAs diode laser and argon plasma coagulation were applied in non-contact mode at gradually increasing power levels and duration and the effects were observed. The use of argon plasma coagulation on Esophagocoil stent seems safe in power settings of 100 W up to 10 s. The diode laser is intermediate in that Gianturco and Esophagocoil stents can withstand pulses of up to 50 W for about 2 s. The Nd-YAG laser is detrimental to most stents at power levels of 20 W. Only the Esophagocoil withstands Nd-YAG pulses of 60 W but only up to 1 s. Wallstent, open and membrane-covered mesh stents perform poorly in that they can only tolerate up to 1.5 s of power at 25 W with the Diode and 1.0 s of power at 20 W with Nd-YAG laser. The use of different thermal modalities on the five stents has indicated safe power limits and duration. Membrane-covered stents are always damaged by thermal laser application unless the membrane is truly transparent.

Keywords: Argon plasma coagulation; Expandable metal stents; GaAlAs diode laser; Nd-YAG laser; Stent overgrowth

BACKGROUND AND AIM

Expandable metal stents (EMS) are rapidly replacing semirigid stents as the prostheses of choice for the palliation of inoperable oesophageal cancer [1–3]. They can be placed with relative ease and safety and give a good functional result in terms of relief from dysphagia [4–6]. Nonetheless, as experience with these stents grows, it has become clear they are not without problems. One frequent reason for loss of stent patency is tumour overgrowth [7–9]. In those stents designed with an open mesh or coil, tumour may grow in through the sides of the stent. Others incorporate a plastic sheath or membrane covering to prevent ingrowth but are still susceptible to overgrowth of tumour at the proximal or distal ends of the stent. Furthermore, many covered stents have terminal uncovered portions through which ingrowth can occur.

Whatever type of tumour ingress occurs, the result is dysphagia and further therapy is required. One option is coaxial placement of another stent [8–10]. Alternatively the obstructing tumour can be destroyed by thermal ablation using laser or argon plasma coagulation (APC) [8,11–14]. Given the high cost of EMS, this is likely to be a more cost-effective solution and is the preferred approach in many centres. Despite the widespread use of thermal destructive methods for clearing stents, little is known about the ability of the prostheses themselves to withstand damage when exposed to laser or APC energy.

Stents in common use are constructed from surgical grade stainless-steel alloy filaments woven in a tubular mesh. The membranes used in covered stents are made from silicone. Both the metal strands and the membranes can be damaged by thermal laser [7,11,13]. Very little

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information is available on the effects of APC on stent components.

The longer the EMS is in situ, the greater the likelihood of ingrowth/overgrowth and hence the need for laser ablation or APC therapy [11,13,14]. Thus the effect of the thermal ablation process on the metal stents needs to be assessed. We studied the effects of laser and APC on five types of stents to determine the power and duration that can be safely applied without damaging the stents.

MATERIALS AND METHODS

The following instruments were used.

1. High power neodymium–yttrium–aluminium–garnet (Nd-YAG laser), 50–70 W operating at 1064 nm. Laser pulses were usually applied for 1–3 s.
2. Gallium–aluminium–arsenide (GaAlAs) semiconductor diode laser operating at 810 nm (25–45 W). Although short pulses of 1–2 s can be applied, continuous application for up to 10 s is more usual. Both forms of laser have been shown to be effective, relatively safe, and easy to apply with the patient under intravenous sedation.
3. Argon plasma coagulation (APC) is a means of applying a monopolar electrosurgical current to tissue via an ionised argon gas stream (argon plasma). The argon gas remains ionised for 2–10 nm distal to the tip of the applicator where the energy delivery to the tissue is uniform, contact-free and penetrates to a maximum coagulation depth of about 3 mm. The usual power level is 65 W and continuous application is used.

The following stents were tested (Fig. 1):

1. Wall stent;
2. Open mesh metal stent (uncovered Ultraflex, Boston Scientific);
3. Covered mesh metal stent (covered Ultraflex, Boston Scientific);
4. Esophagocoil (Medtronic);
5. Gianturco (or ‘Z-stent’) (Wilson Cook).

Nd-YAG laser (Flexilase, Living Technology, Pilkington) and GaAlAs diode laser (Diomed, Cambridge) were applied in a non-contact mode at about 10 mm from the stent surface. The argon plasma coagulator (ERBE, Tubingen) was used in a non-contact mode, as close as possible to the surface of the stent.

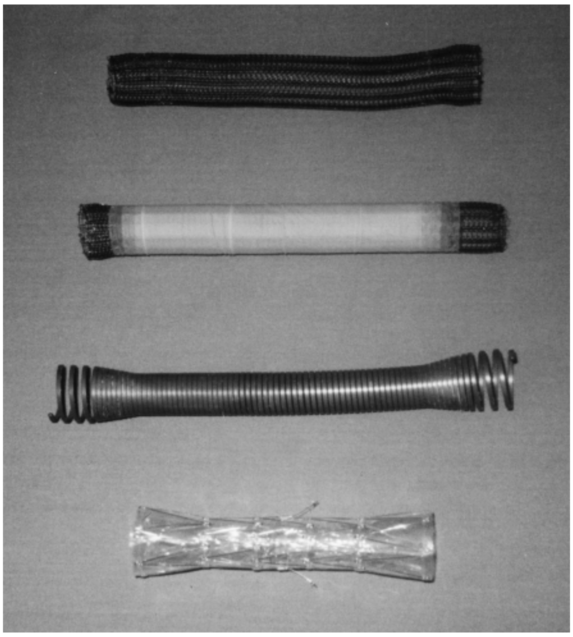

Fig. 1. Expanding metal stents (top to bottom): open-mesh metal stent; covered-mesh metal stent; Esophagocoil; Gianturco (Z stent).

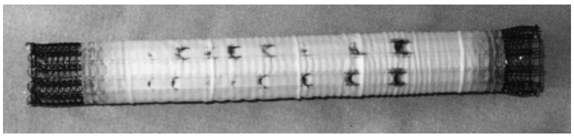

Fig. 2. Laser beam damage on the membrane of the covered stent.

Fig. 3. ‘Pitting’ on metal coil of Esophagocoil.

The lasers were applied to the stents at gradually increasing power settings, starting at 20 W and increasing to 100 W. The duration was also increased in increments of 0.5 s up to 10 s. The effects on the stents were then observed. The earliest sign of damage was noted. The membrane covered stents developed tiny holes in the membrane (Fig. 2) whereas the Esophagocoil stents developed pitting on the metal surface (Fig. 3). The final endpoint was taken when the stents visibly melted. Open mesh stents did not show any early signs, and the first sign of damage was melting of the strands of the stent.

Table 1. Thermal application of APC, Nd-Yag and GaAIAs diode lasers to five stents, showing time up to which the stents are not significantly damaged

Stent type	Power setting								
APC			50 W		65 W		75 W		100 W
Wallstent			1 s		1 s		*		*
Open			1 s		1 s		*		*
Cover			1 s		1 s		*		*
Giant.			5 s		5 s		3 s		3 s
Esoph.			10 s		10 s		10 s		10 s
Diode laser	20 W	25 W	30 W	35 W	40 W	45 W	50 W	55 W	60 W
Wall stent	1.5 s	1 s	*	*	*	*	*	*	*
Open	1.5 s	1 s	*	*	*	*	*	*	*
Cover	1.5 s	1 s	*	*	*	*	*	*	*
Giant.	5 s	3 s	1 s	0.5 s	0.5 s	*	*	*	*
Esoph.	10 s	10 s	5 s	3 s	3 s	3 s	3 s	3 s	1 s
Nd-Yag laser	20 W	25 W	30 W	35 W	40 W	45 W	50 W	55 W	60 W
Wall stent	1 s	*	*	*	*	*	*	*	*
Open	1 s	*	*	*	*	*	*	*	*
Cover	1.5 s	*	*	*	*	*	*	*	*
Giant.	1.5 s	*	*	*	*	*	*	*	*
Esoph.	5 s	5 s	2 s	2 s	2 s	1.5 s	1 s	1 s	1 s

Open, open-mesh metal stent; cover, covered-mesh metal stent; Giant, Gianturco or Z stent; Esoph, Esophagocoil.
*Stent destruction.

A glowing effect on the metal surface of the stent was sometimes noted, but as this was seen only during the laser application and appeared to result in no permanent damage it was taken as safe from the point of view of integrity of the stent although the patient may experience discomfort from heat transference during the clinical procedure.

RESULTS

The effects of laser and APC on the stents are shown in Table 1. For the purpose of brevity, only those power settings causing stent damage are recorded. According to this in vitro study, argon plasma coagulation appears to have less potential for damaging stents than the other two laser modalities (Table 1c). APC can be applied for 10 s at a power setting of 100 W in the presence of the Esophagocoil and 6 s at a power setting of 75 W in the presence of the Z-stent. Wallstent, open, and covered mesh stents could only withstand APC at a setting of 65 W for up to 1 s.

Diode laser causes less damage than Nd-YAG laser (Table 1b). At a power setting of 30 W this can be applied for up to 5 s with the Esophagocoil and up to 2.5 s with the Z-stent but the ‘safe’ limits of power setting and duration may not be sufficiently clinically effective to treat tumour ingrowth/ overgrowth. Wall stents, open and covered mesh stent could be safely treated to an upper limit of 1.5 s exposure at a power level of 25 W.

Nd-YAG laser damages the stents at much lower settings (Table 1). At a power setting of 20 W, the Wall stent and open mesh stent lasted for only 1 s whereas the covered mesh and Gianturco were maintained intact up to 1.5 s. The Esophagocoil was undamaged up to a maximum of 60 W but for only 1 s. The Nd-YAG laser must be used with great care in patients with oesophageal stents irrespective of the stent type.

DISCUSSION

Patients with overgrowth of oesophageal stents usually present with recurrence of dysphagia. Once metal stents are in place for longer than 2–3 weeks they cannot be readily removed because they are incorporated in to the wall of the oesophagus due to epithelialisation and granulation formation. A method of tumour clearance must be found. Treatment offered needs to be effective, safe and preferably done on an outpatient basis and capable of being repeated. These objectives can certainly be achieved by laser therapy to the overgrowth. However, during the process there is a possibility that the metallic stent may be damaged [11]. We have investigated the safe level of power and duration with three thermal modalities on five commonly used stents.

Semirigid tubes were initially used for palliation of oesophageal malignancies [15,16]. Nd-YAG laser and diode lasers have been a mainstay of oesophageal tumour ablation therapy since the early 1980s, and before the development of EMS, were the primary means of palliation [17–20]. APC is a more recent development but is rapidly gaining in popularity because of its ease of use and safety [21–23]. Photodynamic therapy is another safe modality in tumour ingrowth of coated and non-coated stents but the process of treatment is inconvenient for the patient and also expensive when compared with thermal ablation [24,25].

Nd-YAG lasers are bulky and require special electrical and plumbing connections if water is used as a coolant, but they have a higher tissue penetration and are useful for ablation of large exophytic tumours.

Semiconductor diode lasers are small and portable and do not require special electrical or plumbing facilities. In non-contact mode there is good absorption of diode laser producing more localised vaporisation than with Nd-YAG although penetration is less because of its lower wavelength. It can be used in continuous mode or pulsed application.

APC results in better visualisation because of low volume of smoke, but depth of penetration is limited. It can be used in pulses or continuously for coagulating large bleeding surfaces but is less effective in debulking large tumours [21]. This is less likely to be a problem since the volume of tumour blocking a stent is typically quite small.

Our studies confirmed that for a given power setting the diode laser was tolerated for longer periods than Nd-YAG laser before stent damage occurred. When different stents are compared, Esophagocoil is more resilient and the open mesh stent the most easily damaged. The relative vulnerability of the five varieties of stent was the same for both laser modalities. (Esophagocoil>Gianturco> covered mesh stent>open mesh stent/wall-stent). For each laser modality, it is possible to define a 'safety limit' of power and duration below which damage does not occur (Figs 2 and 3). When lasers were applied direct to the transparent membrane of the Z stent, no damage occurred to the membrane, but the heat energy was still transmitted through the membrane, as evidenced by the burning of the cloth beneath the stent observed in our studies. At clinically useful powers and duration, limited stent damage was always seen with all the stents that we used, although the integrity of the stents was not necessarily compromised. With APC, however, which is usually applied at 65 W, the metallic component of all stents survived brief exposure but only the Z stent and Esophagocoil can survive more than 5 s or so. The membrane is consistently damaged by any direct thermal contact except for the briefest exposures.

Other considerations that may determine the choice of a particular modality in this situation include extent of overgrowth, presence of bleeding (APC preferred choice), type of stent in place and local availability of the type of laser/APC.

It is apparent that individual stents have different abilities to withstand radial forces [26,27]. It follows, therefore, that weakening of the stent caused by heat damage from the laser while clearing obstructing tumour may be an additional fact diminishing the capacity of the stent to resist compression and ingress by encasing tumour. There is, to date, little information to indicate which stent is most suitable for a particular patient or type of tumour.

Availability of different types of lasers depends largely on their cost. Lasers are expensive (Nd-YAG laser about £45 000–60 000; GaAlAs diode laser about £45 000) and may be available only in special centres. APC is relatively cheap (£15 000) and hence more readily available. Even though its use in primary ablation therapy may be limited, it undoubtedly has a place in the treatment of stent overgrowth [28].

Our preliminary studies have shown APC to be safe when used with stents. This in vitro study has shown that Nd-YAG laser is likely (in higher power settings) to destroy the metal stent and this is true with diode laser but to a lesser extent. However, perhaps it is worth pointing out that in clinical practice, the diode laser is unlikely to cause any significant damage [11].

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