Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofSurgicalResearch.com

More compression improves sealing effect on larger pulmonary arteries

Andreas Kirschbaum, MD,[a,*] *Franziska Rüdell,*[a] *Anika Pehl, MD,*[b] *and Detlef K. Bartsch, MD*[a]

[a] *Department of Visceral, Thoracic and Vascular Surgery, Giessen and Marburg University Hospital (UKGM), Marburg, Germany*

[b] *Institute of Pathology, Giessen and Marburg University Hospital (UKGM), Marburg, Germany*

ARTICLE INFO

Article history:
Received 21 May 2015
Received in revised form 12 August 2015
Accepted 24 September 2015
Available online 14 October 2015

Keywords:
Bipolar blood vessel sealing
MARSEAL
SealSafe
Bursting pressure
Compression force
Compression duration
Pulmonary artery

ABSTRACT

Background: Small arteries and veins up to 7 mm can be sealed safe and divided with a bipolar sealing instrument. The results for the safe sealing of larger vessels were unsatisfactory in the past. Using an *ex vivo* pulmonary artery model, we aimed to investigate, if a higher compression force and duration will improve the bursting pressures in case of vessels >7 mm.

Material and methods: Heart-lung preparations (from 90 kg pigs) were removed *en bloc* at a slaughterhouse. The whole pulmonary artery was exposed from the pulmonary valve up to the periphery of the left lung. In the laboratory, a digital pressure sensor was implanted in the central end of the blood vessel to measure the bursting pressure (in mbar). The vessels examined were divided into three groups by diameter: 1–6 mm, 7–12 mm and >12 mm. After bipolar sealing, bursting pressures were determined by pneumatic testing. Seals were made using three equal MARSEAL instruments (Gebrüder Martin GmbH & CoKG, Tuttlingen, Germany) with a SealSafe G3 electric current and different jaw compression forces of each 35 N, 45 N, and 55 N. Bursting pressures were also measured for different compression durations (0 s, 5 s, 10 s, and 20 s) with 35 N compression. Mean bursting pressures were calculated for each group ($n = 15$). Groups were compared using a nonparametric test (Mann–Whitney *U* test). The significance level was $P < 0.05$.

Results: Mean bursting pressures in the 1–6 mm blood vessels were 290.5 ± 77.1 mbar (35 N), 323.0 ± 76.0 mbar (45 N) and 301.6 ± 69.9 mbar (55 N). The groups did not differ significantly. Mean bursting pressures in the 7–12 mm vessels were 108.1 ± 19.1 mbar (35 N), 154.3 ± 28.5 mbar (45 N), and 212.4 ± 45.3 mbar (55 N). In blood vessels >12 mm in diameter, we found mean bursting pressures of 77.7 ± 11.7 mbar (35 N), 117.6 ± 27.1 mbar (45 N), and 166.3 ± 56.6 mbar (55 N). The results for the groups with 55 N compression were significantly higher than for the other groups. A compression duration of 5 s led to significantly higher mean bursting pressures than a duration of 0 s but a duration of >5 s did not bring a further significant increase in mean bursting pressure. Histologic staining of the seal zone and microscopic examination did not reveal any differences relating to compression force.

* *Corresponding author*. Department of Visceral-, Thoracic- and Vascular Surgery, Baldingerstrasse, D-35033 Marburg, Germany. Tel.: +49 6421 58 62561; fax: +49 6421 58 66593.

E-mail address: akirschb@med.uni-marburg.de (A. Kirschbaum).

http://dx.doi.org/10.1016/j.jss.2015.09.031

Conclusions: With a higher compression force, we reached satisfactory bursting pressures in case of pulmonary arteries >7 mm. An additional 5 s of compression before starting coagulation brings a further significant increase in bursting pressure. However, there is no advantage in a longer compression.

1. Background

Bipolar sealing is used successfully in many areas of surgery. In thyroid resection, the use of bipolar sealing instruments has been shown to lead to significant reductions in both operating time and complication rates [1,2] but may be associated with increased purchasing cost [3,4]. With regard to complications, bipolar sealing is superior to alternative methods of blood vessel closure such as ligature, the use of clips, and bipolar diathermy [5]. A harmonic scalpel and bipolar sealing produce comparable results [5]. In the resection of liver tissue, bipolar sealing achieves significantly better results than Cavitron Ultrasonic Surgical Aspirator [6] with regard to intraoperative blood loss and rates of postoperative bleeding. Chiappa *et al.* [7] have reported safe use of a bipolar sealing instrument in 116 patients undergoing liver surgery. However, they noted that the blood vessels subjected to bipolar sealing were all <7 mm in diameter. All larger vessels were closed by suture ligation. Even the closure of bile ducts appears to be more efficient with a bipolar sealing instrument [8]. This contrasts with the experimental findings of Hope *et al.* [9] which included a relatively high failure rate in a pig model. In spite of the possible increase in thermal tissue damage (the bipolar sealing group showed a temporary increase in transaminases), this does not appear to affect the rate of postoperative complications [10]. A further advantage of bipolar sealing is its use in endoscopic surgery. A study by Hubner *et al.* [11] showed that a 5 mm bipolar instrument was superior to a 10 mm device in laparoscopic colon surgery. The use of a harmonic scalpel and bipolar sealing are also equally valuable in endoscopic surgery [12,13]. To use this method successfully to coagulate blood vessels it is essential to have precise knowledge of the special technology involved [14].

If the bipolar sealing technique is to be optimized and used in a wider range of settings (e.g., to seal blood vessels >7 mm in diameter) it is necessary to consider the individual factors influencing its effect. A bipolar sealing instrument is a clamp-like device with jaws of different lengths. When these are closed they exert a defined compression force. This results in compression of the elastin and collagen fibers in the blood vessel. The thermal energy heats the blood vessel leading to denaturing of the collagen fibers, which then bind in new ways. The heated elastin fibers ensure adequate tissue elasticity, making the seal mechanically strong. The right ratio of collagen to elastin is important for successful vessel sealing [15]. The size of the blood vessel also appears to be important for the quality of the seal [16]. The bipolar sealing instrument is connected to a generator capable of producing electric current of different strengths. Once coagulation has started the device is able to measure the impedance of the tissue continually at a defined current strength. The coagulation procedure is stopped when a certain threshold value is reached. In an experimental trial with pig arteries, Wallwiener *et al.* [17] showed that impedance controlled coagulation is superior to conventional coagulation. We investigated pulmonary arteries [18] and found that impedance controlled bipolar coagulation is at least equal to conventional bipolar coagulation. In a further own study [19] the mean burst pressures of pulmonary artery vessels > 12 mm were unsatisfactory low, only 52.1 ± 15.1 mmHg. To improve these results, may be a higher compression force resulting in a better contact of the elastin fibers before starting the coagulation, can solve this problem. Furthermore the duration of compression may play a role for the sealing quality. So we want to investigate these issues on our *ex vivo* model of the pig pulmonary artery [19].

2. Material and methods

Undamaged heart-lung blocks were removed from freshly killed pigs (European unit standard weight, 90 kg) at a slaughterhouse. Each preparation was first inspected to ensure that the whole pulmonary artery was undamaged. The left pulmonary artery was exposed from the pulmonary valve up to the periphery of the left lung. The right trunk of the pulmonary artery was severed above the pulmonary valve and the resulting left-side blood vessel–lung preparation was removed. The pulmonary artery was exposed up to the periphery so that blood vessels of varying diameter could be examined. The individual preparations were packed in damp gauze and taken to the surgical hospital's laboratory. After arrival, all the pulmonary artery branches were inspected again up to the periphery for any damage. A pressure transducer dome was implanted without air leaks on the central side. The pressure transducer was connected to a digital manometer (GDH 200–13; GHM Messtechnik, Greisinger site, Regenstauf, Germany). The individual arterial branches and the opening to the main trunk of the right pulmonary artery were closed with clamps giving an airtight seal. The size of each blood vessel was measured with calipers, and vessels were allocated to size groups accordingly. Bipolar sealing of the relevant blood vessels was carried out with a MARSEAL5 instrument and SealSafe G3 electric current (Gebrüder Martin &Co KG, Tuttlingen, Germany). A pneumatic load was applied to the seal till the bursting pressure was reached (in mbar, Fig. 1), indicated by a digital manometer. Three size groups of pulmonary arteries (each with $n = 15$) were examined. Their diameters were 1–6 mm, 7–12 mm, and >12 mm. Our routinely useable clinical bipolar instrument has a jaw compression force of 35 N. Especially for this study, we constructed two further instruments with additional compression forces of 45 N and 55 N. More than 55 N of compression