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Comparison between 3 Aortic Clamps for Video-Assisted Cardiac Surgery: A Histological Study in a Pig Model

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ABSTRACT

Objectives. To assess histological traumatic effects of aortic clamps used in video-assisted surgery, an experimental study was undertaken in a pig model, comparing the Portaclamp, Endoclamp, and a metallic clamp.

Material and Methods. In 3 groups of 5 pigs each, the descending aorta was exposed through a posterolateral left thoracotomy. External clamps (Portaclamp and metallic clamp) were positioned at the middle of the aorta. Endoclamps were inserted at the top of the descending aorta through a small purse and inflated lower. After 60 minutes of clamping, the clamp was removed and the animal reperfused for 60 minutes. It was then sacrificed and the descending aorta was harvested for blind histological study using hemotoxylin-eosin staining of 4 samples per animal: A, before the clamping spot; B, at the clamping spot; C, after the clamping spot; D, a remote sample as control.

Results. In the Portaclamp and metallic clamp groups, there were no lesions of the intima in all aortic samples. In the Endoclamp group, severe lesions of the intima were observed on the clamping spot: endothelium crushing with flattening of cell nucleus (3/5) or endothelium stripping with vanishing of cell nucleus all gathered in 1 point (2/5). Only spongy lesions (clearance between fibers) located on the external third of the media and moderate inflammatory lesions of the adventice were observed with a random distribution in aortic samples without difference between groups.

Conclusions. This study reveals the impressive lesions of the aortic intima due to the Endoclamp. The nonspecific lesions observed in media or adventice may be related to the surgical trauma of the procedure.

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INTRODUCTION

Since the mid 1990s, video-assisted cardiac surgery has gained interest along with the development of new cardiopulmonary bypass (CPB) techniques and, more recently, robotic assistance. Mitral and septal surgery, as well as coronary surgery, became possible with the introduction of endo-CPB systems that allow cardiac assistance and arrest, owing endovascular aortic clamping to fluoroscopy- or transesophageal echocardiography (TEE)-guided balloons [Galloway 1999]. In parallel, standard femoro-femoral CPB is still used, and in this case, aortic clamping is performed with a solid body transthoracic clamp passed through a port [Chitwood 1997]. Although some studies have already compared the different clamping techniques effect on postoperative morbidity and mortality, there is no analysis of the direct effect of the different clamping techniques upon the aortic tissue itself [Reichenspurner 2005].

The aim of the present study was to analyze the effect of 3 different vascular clamps used in video-assisted cardiac surgery on the aortic wall in an experimental model in a pig.

MATERIAL AND METHODS

Animals

Adult pigs weighing approximately 35 kg were used. All animals received human care in compliance with the "Guide for the Care and Use of Laboratory Animals" published by the US National Institutes of Health (NIH Publication No. 85-23, revised 1996). The experimentation did not receive support from any company.

General Surgical Preparation

Pigs were premedicated with 0.25 mL/kg intramuscular 2% xylasine (Rompun; Bayer HealthCare, West Haven, CT, USA). Venous access was obtained through a 24-gauge IV catheter placed in a marginal ear vein. Anesthesia was induced and maintained using intravenous nesdonal (20 mg/kg and 20 mg/kg per hour, respectively). A continuous perfusion of hydroxyethyl amidon (6%, 15 mL/h) was started and maintained throughout the experiment. After general heparinization (500 UI/kg), the animals were ventilated through a standard tracheal intubation at a rate of 3.5 L/min and 60%

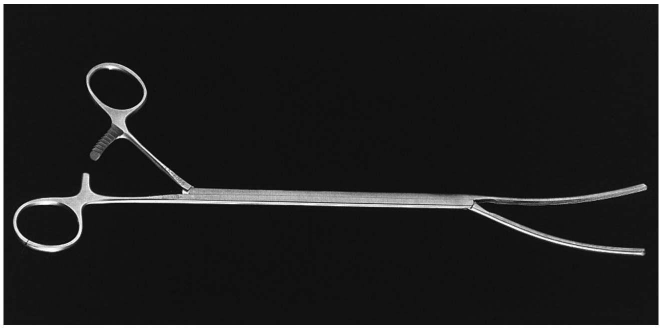

Figure 1. View of the crocodile-like jaws of the Chitwood clamp.

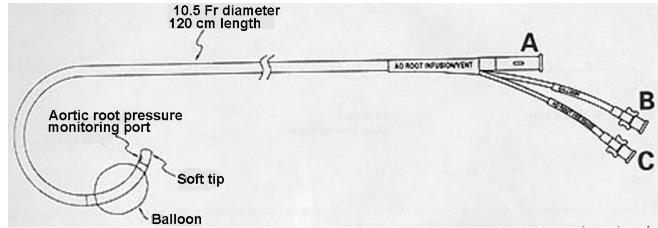

Figure 3. View of the Endoclamp. Two versions allowing direct or femoral clamping are available.

oxygen fraction. The expired partial CO_2 was measured after equilibration. A 20-gauge catheter was placed in the right carotid artery after exposition for continuous monitoring of systemic mean arterial pressure (MAP) and heart rate (BPM). Another catheter was inserted through the internal jugular vein for central venous pressure control. A posterolateral left thoracotomy was performed in the eighth intercostal space and the ninth rib was removed for better exposure. The descending aorta was dissected. A prosthetic 10-mm Dacron shunt was placed between the proximal and the distal segments of the descending aorta to avoid hemodynamic instability during clamping. These end-to-side sutures were made under lateral clamping, using 4/0 polypropylene sutures. The clamp was positioned between the 2 lateral anastomosis of the shunt in a no-touch aortic region, and the aorta was totally occluded.

Experimental Protocol

Pigs were randomized into 3 experimental groups of 5 animals each. In the metallic clamp group (TTC), pigs were subjected to 60 minutes of aortic occlusion with a Chitwood clamp (Scanlan, St. Paul, MN, USA; Figure 1), followed by 60 minutes of reperfusion. In the Portaclamp group (PTC), animals had 60 minutes of aortic occlusion using the endoscopic Portaclamp (Cardiolife Res, Leuven, Belgium; Figure 2), then 60 minutes of reperfusion. In the Endoclamp group (ENDO), an Endoclamp (Cardiovations, Somerville, NJ, USA; Figure 3) was inserted at the top of the descending aorta through a purse string. It was then inflated between the 2 lateral anastomosis with an inflation pressure maintained between 280 and 350 mmHg. Occlusion and reperfusion were comparable to the 2 previous groups.

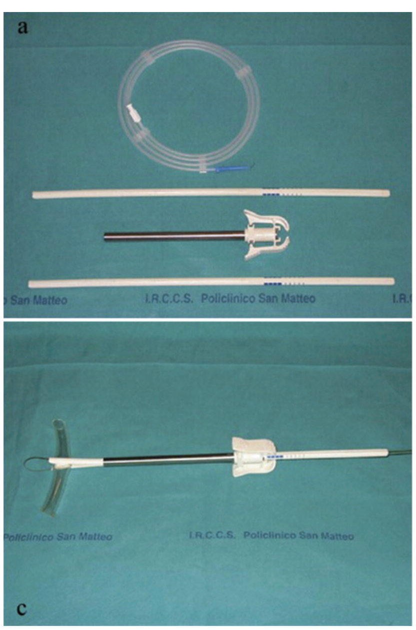

Figure 2. View of the Portaclamp. Note the guide wire that allows easy positioning through the transverse sinus.

Histological Analysis

At the end of the reperfusion period, the animals were sacrificed and the descending aorta was harvested for blind histological analysis, using hematoxylin-eosin staining. The analyses concerned all the circumference of the aortic wall and were made on 4 samples per animal: 1 cm before the clamping place (A), at the clamping place (B), 1 cm after the clamping place (C) and a remote sample as control (D). Histological examinations were focused on the aortic intima, media, and adventice. Samples were classified as normal, stripping, or crushing for the endothelium, normal or spongy for the media, and normal or inflammatory for the adventice.

RESULTS

No significant difference existed between the 3 groups concerning the weight of the animal and the diameter of the aorta. All the procedures were driven until the end of the reperfusion period.

Intima Lesions

We did not observe lesions of the intima in the TTC and PTC groups. In the ENDO group, the intima was normal for points A, C, and D in all animals. At point B, 3 animals presented with endothelium crushing (Figure 4) and 2 had endothelium stripping (Figure 5). We did not observe intima rupture in any case.

Media/Adventice Lesions

Spongy lesions, defined as clearance between fibers, located on the external third of the media, were observed regardless of animal, clamping technique, or location. Moderate inflammation of the adventice was noted with random distribution, without difference between groups and location.

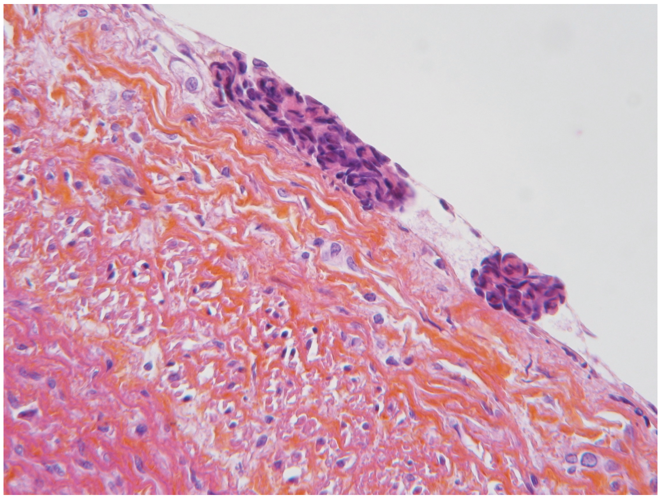

Figure 4. Microscopic aspect of the endothelium in the ENDO group. The endothelial cells are stripped and gathered in 1 point (ES lesions).

We did not observe media break or adventice hematoma. Data are reported in Table 1. The average of normal media in every group is reported in Table 2.

DISCUSSION

Video-assisted cardiac surgery has become a routine technique since the mid 1990s, allowing for the development of different types of interventions, coronary as well as valvular. Because the access to the great vessels is reduced, 2 different strategies were adopted for aortic clamping, endovascular occlusion balloons (Endoclamp; Cardiovations) or transthoracic port-adapted solid clamps [Chitwood 1997; Galloway 1999]. Yet each technique has its own inconveniences. The use of the Endoclamp was associated with aortic dissection in the beginning of the international experience, and solid transthoracic clamps oblige the surgeon to perform cardioplegia in the aortic root through the tiny access space [Chitwood 1997; Galloway 1999]. Some recent studies have compared the 2 different approaches effect on morbidity [Reichenspurner 2005]. But to our knowledge, there is no reported study dealing with the direct impact of these different clamping techniques on the aorta itself. This experimental study was carried out to analyze the histological lesions on the aortic tissue caused by the different clamps.

In our study, the use of the transthoracic clamps (TTC and PTC animals) did not promote endothelial injury. Fur-

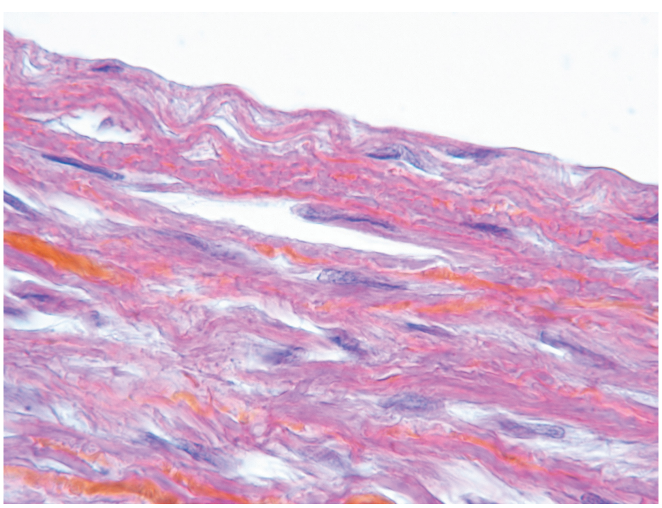

Figure 5. Crushing of the endothelial cells in microscopy. Cell nuclei appear to be flattened (EC lesions).

Table 1. Comparison between Groups for Media/Adventice Lesions*

	Media/Adventice Samples			
Animals	A	B	C	D
		TTC group		
1	S/I	S/I	N/I	S/I
2	N/N	N/N	S/N	S/N
3	N/N	S/N	N/I	S/I
4	N/N	S/N	S/I	N/N
5	S/I	N/N	S/I	N/N
		PTC group		
6	S/N	N/N	S/N	S/N
7	S/N	S/I	S/I	S/I
8	S/I	N/N	S/I	S/I
9	S/I	S/I	S/I	S/I
10	S/N	N/N	S/N	S/N
		ENDO group		
11	N/N	S/I	N/I	N/N
12	S/I	S/N	S/N	N/I
13	N/I	N/N	S/I	S/I
14	S/N	N/N	N/I	N/N
15	N/N	S/I	N/N	S/I

*There was no significant difference among animals, clamping technique, or location of the examined segment. A is a sample taken from a section 1 cm before the clamping zone; B, at the clamping zone; C, 1 cm after the clamping zone; D, remote sample. TTC indicates metallic transthoracic clamp; S, spongy; I, inflammatory; N, normal; PTC, Portaclamp; ENDO, endovascular balloon clamp.

Table 2. Comparison of the Different Normal Samples between the 3 Groups, in Media and Adventice*

	Samples			
	A	B	C	D
No. of normal media				
TTC group	3/5	2/5	2/5	2/5
PTC group	0/5	3/5	0/5	0/5
ENDO group	3/5	2/5	3/5	3/5
No. of normal adventice				
TTC group	3/5	4/5	1/5	3/5
PTC group	3/5	3/5	2/5	2/5
ENDO group	3/5	3/5	2/5	2/5

*A is a sample 1 cm before the clamping zone; B, at the clamping zone; C, 1 cm after the clamping zone; D, remote sample. TTC indicates metallic transthoracic clamp; PTC, Portaclamp; ENDO, endovascular balloon clamp.

thermore, the lesions of the external layers of the aorta were not specific. The Chitwood clamp is a "lobster pincer" clamp that does not apply the same pressure equally over the jaws. This could theoretically promote aortic wall injury at the proximal segment of the clamping zone as the distal part of the clamp is less aggressive. Furthermore, the tip of the clamp is responsible for pulmonary artery and left atrial appendage injuries when used in a blind technique [Felger 2001]. In opposition, the Portaclamp applies the same pressure equally over the jaws. It is a wire-guided clamp and clamping marks on both jaws avoid collateral lesions during clamping [de Canniere 2004]. In both groups, we did not observe major lesions of the aortic layers such as trans-sections or local dissections. Furthermore, the lesions of the media and the adventice were not specific and were randomly observed in all groups. This could be related to the manipulation of the aortic segments during the surgical procedure.

In the ENDO group, major modifications of the endothelium were observed. We had either stripping or crushing lesions at the clamping zone with no specific damage on the other aortic layers. The endo-aortic clamping technique requires a long learning curve [Casselman 2003]. In the beginning of the international experience, some aortic dissections due to vascular injuries in association with retrograde arterial perfusion were described [Galloway 1999]. Reichenspurner et al have recently reported no difference upon mortality and morbidity between transthoracic clamping using a Chitwood technique and endovascular clamping in a prospective study [Reichenspurner 2005]. Nevertheless, the endovascular clamping technique is useful in case of reoperations that limit the access to the aorta. Mueller et al have analyzed the aortic endothelial lesions using an intra-aortic balloon pump in an experimental model in calves [Mueller 2000]. They found that the endothelium was damaged at the inflation zone facing the balloon. Yet endothelial regeneration could be obtained after 14 days with no sequel. This model is the nearest to the one we describe here, even if in our approach the compression of the aortic wall by the balloon is permanent during 60 minutes and not intermittent.

In conclusion, aortic clamping for minimally invasive cardiac surgery can be performed safely with a range of different clamps, external or endovascular. The lesions consecutive to the clamping are basically located at the endothelium in endovascular approach. An experimental study concerning long-term lesions after clamping could be interesting for analyzing the recovery of the endothelium. Both transthoracic and endovascular techniques can widen the operative armamentarium.

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