

Intra-ocular diathermy forceps

Koen A. van Overdam,^{1,2}  Emine Kilic,³ Robert M. Verdijk^{1,4} and Sonia Manning¹ 

¹Department of Vitreoretinal Surgery, The Rotterdam Eye Hospital, Rotterdam, the Netherlands

²The Rotterdam Ophthalmic Institute, Rotterdam, the Netherlands

³Department of Ophthalmology, Erasmus MC University Medical Center, Rotterdam, the Netherlands

⁴Department of Pathology, Section Ophthalmic Pathology, Erasmus MC University Medical Center, Rotterdam, the Netherlands

ABSTRACT.

Purpose: The purpose of this study was to develop intra-ocular diathermy forceps and test them on perfused porcine cadaver eyes.

Methods: We designed two types of 23-gauge intra-ocular bipolar diathermy forceps by modifying commercially available membrane peeling forceps. In the first type, the emitting electrode is connected to one-half of the core and the return electrode to the other half, with one jaw of the forceps attached to each half. In the second type, the emitting electrode is attached to the core and both jaws of the forceps, and the return electrode to the surrounding tube. We compared the new diathermy forceps to conventional intra-ocular diathermy, on perfused porcine cadaver eyes. First-order retinal artery and vein closure was confirmed both by a perfusion study and by histology of the treated vessels.

Results: Type 1 diathermy forceps closed retinal arteries and veins more successfully (five of five and five of five successful treatments, respectively) than Type 2 diathermy forceps (five of five and four of five, respectively) and conventional diathermy (three of five and four of five, respectively). Less energy was used with Type 1 compared to Type 2 and conventional for artery closure (1.5 ± 0.0 versus 4.6 ± 3.3 versus 2.1 ± 0.8 joules, respectively) and vein closure (1.5 ± 0.0 versus 5.4 ± 4.6 versus 2.4 ± 0.8 joules, respectively). Histology of the treated vessels confirmed the perfusion study results.

Conclusion: We designed two types of a new multifunctional intra-ocular instrument with the ability to peel membranes and to grasp, compress and coagulate retinal blood vessels. Both types pose operational advantages compared to current conventional intra-ocular diathermy.

Key words: coagulation – intra-ocular diathermy forceps – perfusion – porcine eye model – retinal blood vessels – retinal hemangioblastoma

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Introduction

Intra-ocular diathermy was pioneered in the 1970s (Parel et al. 1974). Monopolar diathermy coagulated blood vessels, but caused collateral

retinal damage. Bipolar diathermy had narrower coagulation boundaries (Tate et al. 1975; Parel et al. 1983). There have been no advances in intra-ocular diathermy design since the 1980s, in contrast to laparoscopic

surgery, where bipolar diathermy forceps are routinely used since the 1990s (Entezari et al. 2007).

Current bipolar intra-ocular diathermy probes have multiple weaknesses, which become evident during attempted closure of hemangioblastoma feeder vessels (van Overdam et al. 2017). The conventional diathermy probe is point-shaped. The surgeon must push on the blood vessel with the probe to close it and then coagulate it. High energy levels are needed to coagulate the distal vessel wall, leading to collateral damage. Secondly, the tip of the diathermy probe blocks the surgeon's view of the blood vessel and coagulation reaction, unless the surgeon removes the probe from the treated area. Thirdly, in case of iatrogenic bleeding, there is unavoidable delay between the removal of the instrument involved in the bleeding episode and the introduction of the diathermy probe into the eye. This makes bleeding more difficult to control.

Therefore, we designed a new intra-ocular instrument combining the ability to apply mechanical compression from opposite sides, a diathermy function and a membrane peeling function, which addresses these weaknesses.

Materials and Methods

Two types of bipolar diathermy forceps were developed by modifying available single-use 23-gauge peeling forceps (Vitrex, the Netherlands; Bausch & Lomb, US). In Type 1, the emitting electrode is connected to one-half of the core and the return electrode to the other half, with one jaw of the forceps attached to each half of the core. In

Type 2, the emitting electrode is attached to the core and both jaws of the forceps and the return electrode to the surrounding tube. Both types retain membrane peeling function.

The diathermy forceps were tested *ex vivo* on perfused porcine cadaver eyes. The eyes were harvested at a local abattoir immediately after killing the animal and transported in heparinized saline (50 units/ml), in melting ice. The time between eye harvesting and preparation was less than 6 hr.

The ophthalmic artery was cannulated with a 23-gauge cannula. The retinal vessels were accessed via an open-sky approach. The vitreous was segmented with No 05-0740 scissors (Lawton, Germany) and was removed, as much as possible, from the retinal surface, with cotton buds. The eyes were filled with perfluorodecalin (DORC, Netherlands). A blood

column was present in the retinal vessels at the end of the process.

We powered the diathermy instruments with a bipolar coagulator (450 kHz) (Aesculap, Germany), delivering power in 0.1 watt steps. The surgeon adjusted energy duration by foot pedal. A starting power of 1.5 watt was chosen based on published recommendations (Parel et al. 1983).

Fifteen porcine eyes were used, five with Type 1, five with Type 2 and five with a conventional disposable 23-gauge bipolar diathermy (Kirwan Surgical Products, US). We treated a first-order branch of the superior or inferior retinal artery and vein, by either compressing the vessel lumen from both sides with the diathermy forceps or by pushing from above with conventional diathermy, until we saw complete disruption of the blood column, caused by coagulation. We

confirmed the results of the coagulation treatment by perfusing the eyes with 100 ml heparinized (50 IU/ml) succinylated gelatin 4% (B.Braun, Germany) with 30 mg of fluorescein added to it, at 0.1 ml/min, using a microprocessor-controlled dispensing pump (ALT, US).

The eyes underwent standard formalin fixation and paraffin embedding prior to histological examination.

Results

The results of the perfusion study and the energy required to close retinal arteries and veins with conventional, Type 1 and Type 2 diathermy forceps, are given in Table 1.

Two coagulation applications were needed with conventional diathermy in two of five eyes (arteries) and three of five eyes (veins) because the study

Table 1. *Ex vivo* performance of the diathermy forceps compared to conventional diathermy.

Diathermy Type	Eyes (n)	Closure rate		Energy (joules ± SD)		Time (seconds ± SD)	
		Artery	Vein	Artery	Vein	Artery	Vein
Conventional diathermy probe	5	3/5	4/5	2.1 ± 0.8	2.4 ± 0.8	1.4 ± 0.5	1.6 ± 0.5
Type 1 diathermy forceps	5	5/5	5/5	1.5 ± 0.0	1.5 ± 0.0	1.0 ± 0.0	1.0 ± 0.0
Type 2 diathermy forceps	5	5/5	4/5	4.6 ± 3.3	5.4 ± 4.6	1.2 ± 0.8	1.4 ± 1.1

SD = standard deviation.

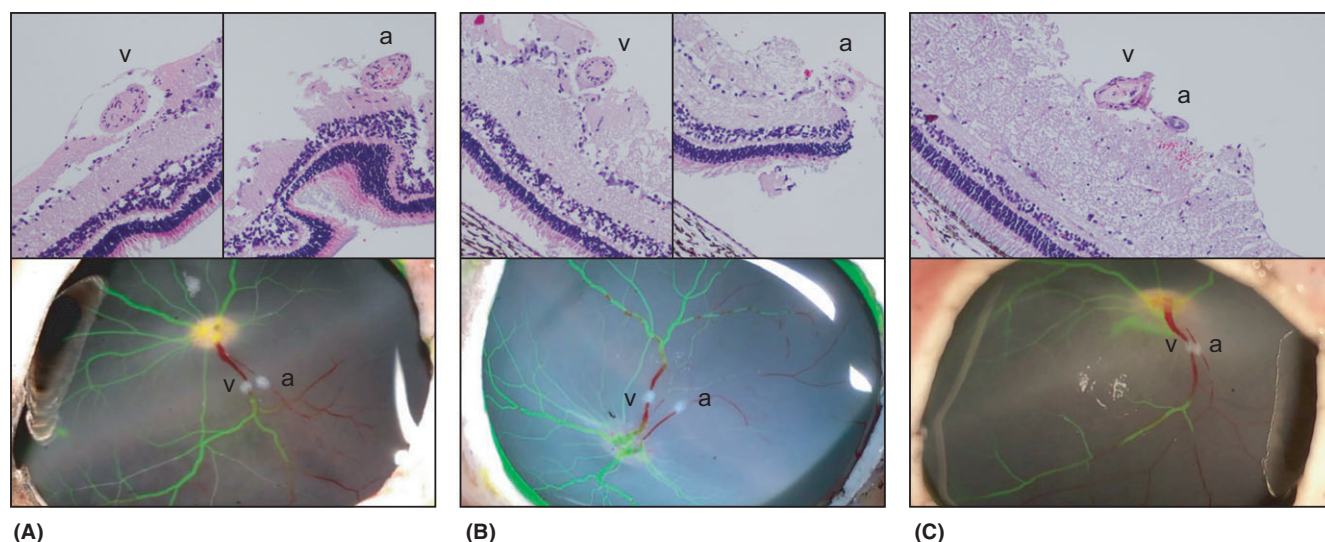


Fig. 1. Fundus photographs and histology slides of coagulated porcine retinal blood vessels. Histology slides (above) and fundus photographs (below) of porcine retinal arteries (labelled a) and veins (labelled v) coagulated with conventional diathermy (panel A), Type 1 diathermy forceps (panel B) and Type 2 diathermy forceps (panel C). In the fundal photographs, the blood columns in the artery and vein have been interrupted by coagulation. The coagulated site and the blood vessel downstream from it show no flow during perfusion of the ophthalmic artery with fluorescein-stained fluid. The histology slides (magnification 100x; haematoxylin and eosin stain) show coagulated and closed retinal blood vessels following application of diathermy. Retinal detachment is a common artefact because of preparation of the eye for the perfusion study and/or tissue processing for histological examination.

investigator did not see sufficient coagulation reaction after the first application.

For Type 2 forceps, the starting power was increased to 4.0 watt because there was no diathermy effect with lower power in the first two eyes. More vitreous was removed from the retinal surface in the remaining three eyes, which reduced the power needed to close the vessels. Use of Type 2 diathermy forceps can be seen in the Video Clip S1.

Histology of the treated vessels confirmed the results of the perfusion study. Both types of forceps closed retinal arteries and veins more effectively than conventional diathermy. Fundus photographs and histology slides of coagulated porcine retinal blood vessels, coagulated with conventional, Type 1 and Type 2 diathermy forceps, are shown in Figure 1.

Comment

This is the first report on two types of a new intra-ocular bipolar diathermy instrument, since the publication by Parel et al. (1983) on the conventional bipolar diathermy probe. Both types, in an *ex vivo* proof-of-concept study, grasp, compress and coagulate retinal blood vessels more effectively than conventional diathermy.

Our design successfully addresses weaknesses of conventional diathermy. Firstly, the blood vessel can be compressed between the jaws of the forceps and be coagulated using lower energy. Secondly, the design ensures visualization of the target blood vessel during the entire coagulation process so the minimum energy necessary is used. The *ex vivo* nature of the model allows for energy requirement comparison between the diathermy forceps and conventional diathermy. The comparison favours the diathermy forceps. Thirdly, the diathermy forceps can be

used as regular micro-forceps, with diathermy continuously available for tissues that are being manipulated and at risk of sudden bleeding.

The presence of vitreous close to blood vessels increased the energy requirements for coagulation when using Type 2 forceps. This may be because the space between the emitting and return electrodes (the jaws and the tube of the forceps) can be occupied by vitreous, which interferes, due to its higher impedance than water, with the electric current. In contrast, in Type 1 forceps, the emitting and return electrodes are connected to the jaws of the forceps with the target blood vessel, but no vitreous, directly between them.

We have designed a new intra-ocular instrument combining the ability to apply mechanical compression on opposite walls of a blood vessel, with a bipolar diathermy and membrane peeling function. This enables the surgeon to have, in effect, multiple instruments, including more effective diathermy, in one hand, meaning that there is no delay between onset of bleeding and coagulation. This will facilitate intra-ocular vascular control.

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Correspondence:

Koen A. van Overdam, MD
The Rotterdam Eye Hospital
Schiedamse Vest 180
3011 BH Rotterdam
The Netherlands
Tel: +31 (0)10 401 77 77
Fax: +31 (0)10 401 77 55
Email K.vanOverdam@oogziekenhuis.nl

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Video Clip S1. Use of the diathermy forceps on a porcine retinal vein and artery. Subsequent perfusion of the ophthalmic artery with fluorescein-stained infusate shows that the coagulated sites and the blood vessels, downstream from those sites, show no flow.