Thoracoscopic infrared ablation to create a box lesion as a treatment for atrial fibrillation

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Abstract

Background: Creating a box lesion in the posterior wall of the left atrium from the epicardial side of the beating heart remains a challenge. Although a transmural lesion can be created by applying radiofrequency (RF) energy at clampable sites, it is still difficult to create a transmural lesion at unclampable sites because the inner blood flow in the unclampable free wall weakens the thermal effect on the outside. Our aim was to apply the newly developed infrared coagulator to create linear transmural lesions on the beating heart thoracoscopically to treat atrial fibrillation (AF).

Case presentation: A 71-year-old male was referred to our hospital with a diagnosis of hypertrophic cardiomyopathy and permanent atrial fibrillation. The patient was first diagnosed with atrial fibrillation 20 years before. Direct current cardioversion had been performed every few years a total of four times, but sinus rhythm restoration had always been temporary. On February 27, 2020, thoracoscopic PV isolation together with infrared roof- and bottom-line ablation to create a box lesion and left atrial appendage amputation (LAAA) were performed. The coagulator could be applied to clinical thoracoscopic surgery to successfully create a box lesion without any complication. The patient restored a regular sinus rhythm, it has been maintained for eleven months, and there have been no adverse events.

Conclusions: The infrared coagulator might have enough potential to create transmural lesions on the beating heart in thoracoscopic AF surgery.

Keywords: Atrial fibrillation, Ablation, Infrared, Infrared coagulator, Epicardial ablation, Epicardial maze procedure, Ex-maze procedure, Box lesion, Thoracoscopic surgery, Left atrial appendage amputation

Background

AF is the most common arrhythmia in clinical setting. Conversion to regular sinus rhythm through catheter based approaches and surgically based approaches has been reported with improved outcomes [1]. The hybrid convergent ablation begets endocardial pulmonary vein isolation, epicardial left atrial posterior wall isolation, so called box lesion, and left atrial appendage ligation clinically [2].

However, creating a box lesion in the posterior wall of the left atrium from the epicardial side of the beating heart remains a challenge. Although a transmural lesion can be created by applying RF energy at clampable sites [3], it is still difficult to create a transmural lesion at unclampable sites because the inner blood flow in the unclampable free wall weakens the thermal effect on the outside. Because the inner blood flow in the unclampable free wall weakens the thermal effect on the outside. Our aim was to apply the newly developed infrared coagulator to create linear transmural lesions on the beating heart thoracoscopically to treat atrial AF.
Technology
The newly developed infrared coagulator is called the “Kyo-co (Photon Co., Ltd., Saitama, Japan).” A reflector focuses light from a tungsten-halogen lamp into a light conducting 8-mm diameter curved-tip quartz rod, and it emerges as 35 W/cm² of near-infrared energy (wavelength, 400 to 1,600 nm; peak wavelength, 850 nm). Power output, ablation time, interval time, and total number of applications can be adjusted as needed, and maximum ablation time is limited to 90 s. The distal exit-plane of the light-conducting rod has a round surface (Fig. 1a-c).

Case presentation
A 71-year-old male was referred to our hospital (Tokyo Metropolitan Tama Medical Center) with a diagnosis of hypertrophic cardiomyopathy and permanent atrial fibrillation. The patient was first diagnosed with atrial fibrillation 20 years before. Direct current cardioversion had been performed every few years a total of four times, but sinus rhythm restoration had always been temporary. The patient’s CHADS2 score was 0. Although he was being treated with edoxaban tosilate monohydrate, he wanted to be free from palpitations, and fear of cerebral infarction. Preoperative transthoracic echography revealed a left ventricular ejection fraction of 65% and left atrial diameter of 56 mm, and there was no valvular dysfunction. Cardiac scintigraphy showed no evidence of myocardial ischemia. The electrocardiogram indicated AF with a 0.2 mV of f-wave amplitude.

On February 27, 2020, thoracoscopic PV isolation together with infrared roof- and bottom-line ablation to create a box lesion and LAAA were performed (Additional file 1: video).

Operative procedure
In 2014, the ethics committee of Kyorin University approved a clinical and epidemiologic study entitled, Surgical treatment of arrhythmias, infectious endocarditis, infected aortic aneurysms, and cardiac tumors with an infrared coagulator (Reference number: H26-048). Written consent was obtained from the patient. The patient was anesthetized through a double-lumen endotracheal tube and placed in the supine position. Transesophageal echocardiography (TEE) was performed with the patient in the optimal position to display the left atrial appendage (LAA). The left lung was allowed to deflate, and 4 endoscopic ports were created in the left lateral thorax: one for a 5-mm, 45-degree camera, another for an endoscopic cutter (EZ45G Endoscopic Linear Cutter, Ethicon Endo-Surgery, Cincinnati, Ohio), and the other two for endoforceps. A 5-cm-long pericardiotomy was made just above the LAA and 2 cm anterior and parallel to the left phrenic nerve, and the ligament of Marshall was sharply divided. An endoscopic light-guided dissector allowed the attached tape to encircle the PVs to enable introduction of the left Atricure clamp coagulator. The clamp coagulator was then used to cross-clamp the left atrium and thereby isolate the left PVs by means of four times of RF ablations. Finally, an Endostapler (ECHOLON FLEX™

Fig. 1  Infrared coagulator “Kyo-co”. a Body of the coagulator. It is connected to a light-guide, foot switch, and vacuum system to cool the light-guide. b Light-guide reinforced with heat-resistant plastic equipped with a light conducting 8-mm diameter curved-tip quartz rod c Exit plane
powered ENDOPATH™ Stapler 60, ETHICON) was used to clamp and amputate the LAA at its root with a single cartridge. Complete hemostasis was achieved. A TEE examination confirmed complete closure of the LAA. An Endoloop ligature was passed around the corner of the cut edge of the LAA, and it was ligated. Then, a Kyo-co infrared coagulator was inserted and applied to the roof and bottom of the left atrium to produce overlapping linear lesions on the left side under the following set of conditions: 85% power, 4 s of ablation, 2 s interval, and 5 applications (Fig. 2).

After completing the procedure on the left side, the operator moved to the right side of the patient, port placements similar to those on the left were made. The connective tissue between the left atrium and right pulmonary artery, and then below the inferior PV was bluntly dissected. The right clamp coagulator was used to achieve four PV isolations, and then the superior vena cava was isolated 5 mm from the right atrium. The Kyo-co infrared coagulator was inserted and applied to the roof and bottom of the left atrium to produce overlapping linear lesions on the right side (Fig. 3).

The operation time was 90 min. The patient was extubated in the operating room, and he was discharged uneventfully on postoperative day 6. Because he was suffered from hypertrophic cardiomyopathy, treatment with edoxaban tosilate monohydrate was continued and amiodarone was administered. Eleven months after the operation, the patient is well; a regular sinus rhythm which was confirmed by electrocardiograms recorded at each outpatient care has been maintained, and there have been no adverse events.

Discussion and conclusions
To manage conventional treatment-refractory persistent AF patients, many catheter based and surgery based approach has been reported. Wats et al. reviewed a
cumulative experience in over 10,000 patients, and con-
cluded that the convergent hybrid procedure now has
an established position in the vast array of procedures
directed at managing non-paroxysmal AF [4]. However,
although several devices capable of creating a box lesion
in the left atrium by an epicardial approach have been
reported, there is still no reliable device available that
can be used to create a transmural lesion on the beating
heart.

Bulava et al. assessed the efficacy of epicardially created
lesions produced with bipolar RF energy in 70 patients
who had persistent AF, and they reported success rates
for creating a conduction block across the bottom line
direc. This study was supported by funding from the “TERUMO Life Science Founda-
Cordation of raw data is impossible as it would conflict with our privacy policy.
Superior and inferior PVs of only 58.0% and 24.3%, respectively [5]. Nath et al.
demonstrated that hyperthermia induced by RF energy
causes significant changes in the electrophysiological
properties of myocardiocytes. They observed reversible
loss of cellular excitability after exposure to tempera-
tures in the 42.7°C to 51.3°C range (median, 48.0°C) for 60 s and
irreversible loss of cellular excitability and tissue injury
after exposure to temperatures >50°C for 60 s [6]. Our
experiment in which we exposed chicken skeletal muscle
to infrared energy showed that tissue temperature rose
to a maximum of 97.9 ± 2.1°C for a total of 28 s (4 s × 5
exposures at 2-s intervals). Thus, theoretically, infrared
energy has a more reliable ability to create a transmural
lesion on a warm, beating atrium than cryothermia does.
Further, because the maximum tissue temperature is far
higher than fat tissue melting point, when we apply the
device, the epicardial fat tissue melts within few seconds
so that the fat tissue does not disturb the thermal effect
on the myocardium.

We previously reported the results of series of animal
model experiments demonstrating that infrared energy
enables creation of a transmural lesion on the canine
beating right ventricle to a maximum depth of 10.3 mm,
and creation of a conduction block on a beating right
atrium [7–10]. Successful electrical isolation of the right
atrial appendage has been confirmed in a clinical setting
[11]. Moreover, using a 30 × 10 mm of cuboid shaped
conducting rod, by confirming the prolongation of con-
duction time between two electrodes put at both side of
the probe, irreversible conduction block could be con-
firmed on a beating right atrial free wall, and this finding
showed that an “electrophysiological transmural lesion”
as well as “histopathological transmural lesion” could be
created on the beating atrium by exposing it to infrared
energy [12].

Ohtsuka et al. have reported the efficacy of thoraco-
scopic LAAA in preventing cerebral infarctions [13]. Our
new approach, which enables rhythm control, adds value
to simple LAAA for AF patients.

No electrophysiological studies were performed on
our patient, however, because direct-current-cardi-
version-resistant chronic AF was converted to regular
sinus rhythm and has been maintained, it might be sup-
porting evidence to prove the effectiveness of our new
device. After the successful treatment of permanent
AF by thoracoscopic epicardial infrared ablation in our
patient, 50 consecutive cases of AF have been treated
in the same procedure safely without any complication.

In conclusion, the infrared coagulator might have
enough potential to create transmural lesions on the
beating heart in clinical thoracoscopic AF surgery con-
comitant with LAAA.

Abbreviations
AF: Atrial fibrillation; LAA: Left atrial appendage; LAAA: Left atrial appendage
amputation; PV: Pulmonary vein; RF: Radiofrequency; TEE: Transesophageal
echography.

Supplementary Information
The online version contains supplementary material available at https://doi.
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Additional file 1. Thoracoscopic infrared ablation to create roof and bot-
tom lesions of the left atrium.

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Authors’ contributions
TO, MH and TN performed the surgical procedure. MN was involved in the
patients’ care. HK, HE, SM, TH, and YI collected the clinical data. All authors
reviewed and approved the final manuscript.

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Availability of data and materials
Supporting data are available upon request to the corresponding author. Pub-
lication of raw data is impossible as it would conflict with our privacy policy.

Declarations
Ethics approval and consent to participate
In 2014, the ethics committee of Kyorin University approved a clinical and
epidemiological study entitled “Surgical treatment of arthromia, infectious
cardiacitis, infected aortic aneurysms, and cardiac tumors with an infrared
coagulator (Reference number: H26-048). Written informed consent was
obtained from the patient.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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