International Journal of Cardiology 197 (2015) 235–240

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

A cross-sectional imaging study to identify organs at risk of thermal injury during renal artery sympathetic denervation☆

Hitesh C. Patel [a,c,*], Sofia Otero [b], Joanna B. Moser [b], Carl Hayward [a,c], Stuart D. Rosen [a,c], Alexander R. Lyon [a,c], Raad Mohiaddin [a,c], Carlo di Mario [a,c], Simon Padley [b,c]

[a] NIHR Cardiovascular Biomedical Research Unit, Royal Brompton Hospital, London, UK
[b] Department of Radiology, Royal Brompton Hospital, London, UK
[c] National Heart and Lung Institute, Imperial College, London, UK

ARTICLE INFO

Article history:
Received 4 March 2015
Received in revised form 15 June 2015
Accepted 19 June 2015
Available online 30 June 2015

Keywords:
Renal denervation
Safety
Anatomy
Ablation
Cross-sectional imaging

ABSTRACT

Background: The technology used to perform catheter-based renal artery sympathetic denervation has evolved: catheters can now access arteries as small as 3 mm in diameter and create ablation zones of up to 10 mm in depth. Recent evidence suggests that the procedure may be more effective if a more thorough ablation strategy is employed. Limited data are available regarding inadvertent soft tissue thermal injury during such procedures. We used computed tomography (CT) to identify structures lying within the expected thermal ablation field or the 'at risk zone' (ARZ).

Methods: 63 consecutive CT aortograms were reviewed, yielding 100 renal arteries anatomically eligible for treatment. Structures lying within a predefined ARZ (within 10 mm of the renal artery wall) were recorded.

Results: The 63 subjects had a mean age of 74.6 years, 48% were males and 88% had hypertension. The inferior vena cava and renal veins were in the ARZ in all cases. Psoas muscles and small bowel were within the ARZ in at least a fifth of the kidneys. Other structures found in the ARZ included the liver, pancreas, adrenal glands and diaphragm.

Conclusions: This study describes the variable anatomical relationship between renal arteries and important abdominal structures that may be exposed to thermal energy during modern denervation procedures. The consequence of delivering such thermal energy to these structures is unknown but clinicians should be alert to the presenting symptoms if these structures are damaged. CT may have a pre-procedure role in assessing this risk.

1. Introduction

Initial studies of renal artery sympathetic denervation as a treatment for resistant hypertension were so encouraging that they promoted investigators to launch studies to evaluate the role of this novel therapy in other conditions associated with sympathetic nervous system over activation [1–7]. For this reason, the results of the Symplicity HTN-3 trial surprised the cardiology community [8]. This trial reported that renal artery sympathetic denervation is ineffective at lowering blood pressure in patients with resistant hypertension when compared to a sham control group. Several hypotheses have been proposed to explain these disparate results [9–12]; one possibility is that the renal sympathetic nerves were inadequately ablated, perhaps due to operator or technological factors [13]. Supporting this hypothesis, a post-hoc analysis of Symplicity HTN-3 demonstrated that those patients who had received a more comprehensive ablation procedure, i.e. a larger number of ablations and therapy to all four quadrants of each renal artery, experienced a greater reduction in blood pressure [14].

Early adopters of renal denervation believed that the superior aspect of the renal artery ostium contained the greatest concentration of sympathetic nerves, and thus considered this a critical site for ablation [15]. This theory has since been dispelled by human histological data, which demonstrates that sympathetic nerves run in closer proximity to the distal rather than proximal renal artery, implying that ablation here may have a superior success rate [16]. This study also found that only 40% of renal sympathetic nerves are located within 2 mm of the artery wall and it is unclear whether the first generation catheter has the capability to extend much beyond this. Newer catheters capable of creating a deeper ablation zone may target a greater proportion of sympathetic nerves and therefore be more effective [17].

Reflecting upon these new data, future trials of renal denervation may employ a more rigorous approach, with ablations being more numerous and more distally placed, including distal to bifurcations,

---

☆ Contributions: HCP and SP devised the study. SO, JBM and HCP collected the data. HCP analysed the data. HCP and CH wrote the first draft. RM, CDM, SP provided supervision. All authors provided critical revisions to the manuscript.Grant support: HCP and CH are supported by the NIHR Cardiovascular Biomedical Research Unit, Royal Brompton Hospital.

* Corresponding author at: Cardiology Research Fellow, Cardiovascular BRU, Royal Brompton Hospital, Sydney Street, London SW3 6NP, UK. Tel.: +44 207 352 8121 Ext 2920; fax: +44 207 351 8146.

E-mail address: h.patel3@rbht.nhs.uk (H.C. Patel).

http://dx.doi.org/10.1016/j.ijcard.2015.06.068

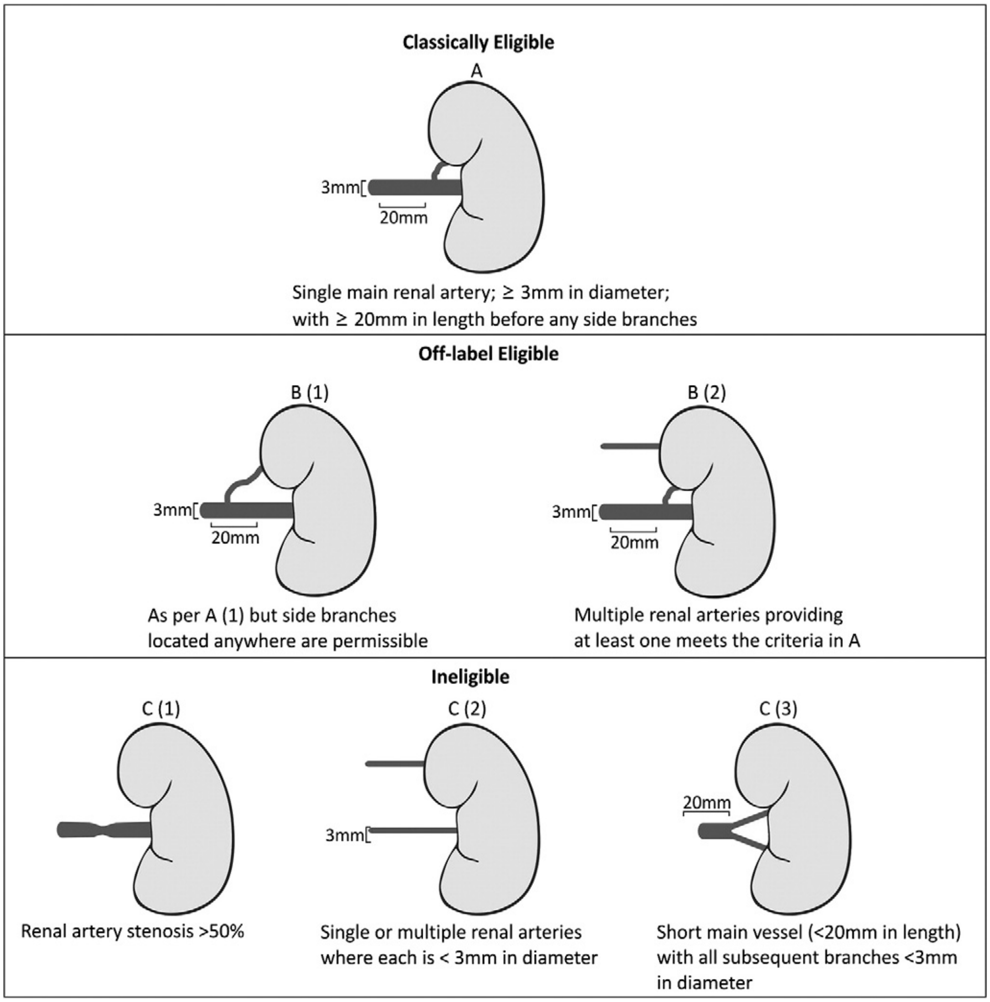

Fig. 1. Classification of eligibility for renal denervation based on renal artery anatomy.

and targeting all four quadrants of the artery [17,18]. Furthermore, it may be desirable to create larger ablation zones [19]. The latest second generation catheters are designed to facilitate this strategy with: 1) multiple electrode configurations that allow uniform circumferential energy delivery (Spyral™, Vessix™, EnlighHTN™ and Paradise™) [15,20]; 2) an ability to perform ablations in arteries as narrow as 3 mm in diameter (Spyral™, Vessix™), thereby enabling more distal access compared to the previous limit of 4 mm [21], and 3) deeper penetration into the renal adventitia (the Paradise™ system is able to create an ablation zone that extends 7–12 mm from the renal artery wall) enabling attenuation of a greater proportion of the sympathetic nerves [22].

Whilst achieving adequate sympathetic nerve attenuation is clearly vital to the efficacy of the procedure, a balance must be struck with the potential risks that may be associated with an extensive ablation strategy that uses the measures outlined above [19,23]. The purpose of this study is to explore one such risk — the potential for ‘comprehensive’ renal artery ablation to cause thermal injury to neighbouring structures. To this end, we reviewed a series of computerised tomograms (CTs) to identify those structures that lie in close proximity to the renal arteries, and which may be exposed to thermal energy using this contemporary approach.

2. Methods

2.1. Study population

Two experienced radiologists independently reviewed consecutive CT aortograms, obtaining a total sample size of 100 kidneys considered anatomically eligible for renal denervation. Demographic data and relevant past medical history were collected for each patient. National Health Service (UK) Management Permission for use of anonymised patient data for research was obtained, conforming to ethical standards [24].

2.2. Renal artery analysis

All images were acquired with a Siemens SOMATOM Definition Flash dual-source scanner, with a reconstructed slice thickness of 0.75 mm [25]. Axial and coronal

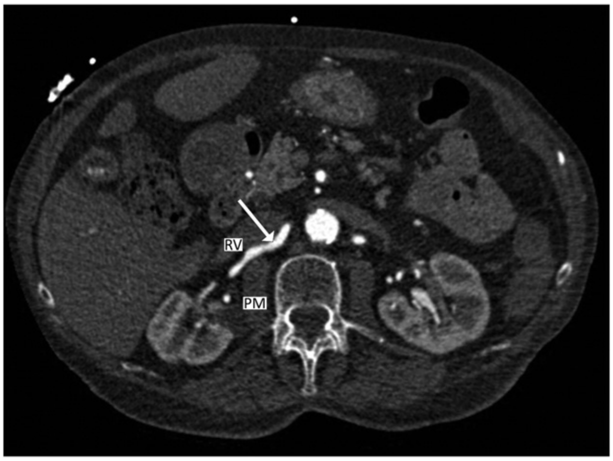

Fig. 2. Axial computerised tomogram showing the close proximity of the right renal artery (white arrow), the right renal vein (RV) and the psoas muscles (PM).