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The Role of Branch Vessels in Aortic Type B Dissection: An *in vitro* Study

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WHAT THIS PAPER ADDS

This *in vitro* study shows that different outflows from branch vessels originating from the false lumen in a type B aortic dissection result in expansion of the cross sectional false lumen area. This might have important consequences for patients with uncomplicated acute type B aortic dissection (ABAD) when patent branch vessel(s) originating from the false lumen, and partial thrombosis (occluding distal tears) or no distal tear are present, as these patients might be at higher risk for developing complicated ABAD.

Objectives: In acute type B aortic dissection (ABAD) a patent false lumen portends a poor outcome. Patent branch vessels originating from the false lumen in a type B aortic dissection are assumed to contribute to persistent blood flow and patent false lumen. Therefore, the morphologic changes of the false lumen generated by different outflow rates in an *in vitro* model were investigated.
Methods: An artificial dissection was created in two *ex vivo* porcine aortas. A thin cannula was placed in the false lumen, simulating a branch vessel originating from it. The aorta was positioned in a validated *in vitro* circulatory system with physiological pulsatile flow (1,500—2,700 mL/minute) and pressure characteristics (130/70 mmHg). The cannula was attached to a small silicone tube with an adjustable valve mechanism. Three different valve settings were used for creating outflow from the false lumen (fully closed, opened at 50%, and fully opened at 100%). Measurements of lumen areas and flow rates were assessed with time-resolved magnetic resonance imaging. In order to study reproducibility, the experiment was performed twice in two different porcine aortas with a similar morphology.
Results: Increasing antegrade outflow through the branch vessel of the false lumen resulted in a significant ($p < .01$) increase of the mean false lumen area at the proximal and distal location in both models. The distal false lumen expanded up to 107% in the case of high outflow via the false lumen through the branch vessel.
Conclusions: Increasing antegrade outflow through a branch vessel originating from the false lumen when no distal re-entry tear is present results in an expansion of the cross sectional false lumen area.

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INTRODUCTION

Uncomplicated acute type B aortic dissection (ABAD) is still associated with a 30 day mortality of approximately 10%.[1] Although the introduction of thoracic endovascular aneurysm repair (TEVAR) showed promising results in complicated ABAD, best medical treatment (BMT) is still an option for uncomplicated ABAD. The acutely dissected aorta is fragile, and TEVAR can result in malperfusion, ischemia, retrograde dissection, rupture, and even peri-operative mortality. The results of the ADSORB trial, as the first randomized comparison between acute (<14 days) endovascular surgery and BMT for uncomplicated ABAD, showed only that aortic remodeling after 1 year favored endograft placement. The ADSORB trial did not show an improved 1 year survival rate (although not powered for survival).[2] The INSTEAD trial, as the first randomized comparison between elective endovascular surgery and BMT, justified medical management in the early phase of uncomplicated chronic ABAD (from 2 to 52 weeks of onset).[1] For stable survivors of ABAD, the benefits of TEVAR begin to show after 2 years of follow up.[3,4] Although the preliminary results of the uncompleted ABSORB trial did not show any beneficial effect of early TEVAR, theoretically early TEVAR might save the lives of around 10% of patients, minus the induced perioperative mortality by TEVAR, with initially uncomplicated ABAD treated with BMT.[2] Therefore, identification of clinical and imaging predictors of poor prognosis in uncomplicated ABAD seems mandatory to select patients who will benefit from early TEVAR.

In an acute ABAD the false lumen may remain patent, thrombose, recommunicate with the true lumen through

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fenestrations, or rupture. Complete false lumen thrombosis is a major predictor of prognosis because it excludes the false lumen from the circulation and is thought to be a prerequisite for complete healing in the long run.[5,6] Incomplete thrombosis or patent false lumen portends a poor outcome.[5,7,8] The occurrence of thrombosis in the false lumen depends on coagulability, endothelial injury/dysfunction, and blood flow. Owing to morphological differences between various types of dissections, the blood flow in the false lumen is highly variable.[9] It is conceivable that patent branch vessels originating from the false lumen in a type B aortic dissection may contribute to persistent blood flow and patent false lumen, and thus to prognosis. Therefore, an *in vitro* study was performed using two *ex vivo* porcine aortas, both with a surgically constructed false lumen and an adjustable outflow branch. The morphologic changes of the false lumen generated by different outflow rates were studied and it was hypothesized that increased outflow through the branch vessel originating from the false lumen would result in an increase of the false lumen.

MATERIALS AND METHODS

Aortic dissection model

Two fresh porcine aortas were obtained from the abattoir and within 4 hours prepared as follows: from the aortic arch to the iliac bifurcation all side branches were ligated with 5.0 Prolene. In the descending aorta a transverse semicircular incision was made though all vessel layers and a dissection was surgically created in the media layer, resulting in a false and true lumen with a dissection flap. The surgically created false lumen in the media may be considered comparable with a human aortic dissection (Fig. 1). A thin plastic cannula (2 mm diameter) was placed in the false lumen simulating a branch vessel originating from the false lumen. The morphology of both models is representative for a type B aortic dissection with no distal tear or partial thrombosis occluding distal tears, impeding outflow, resulting in a blind sac from where a single branch vessel originates (Fig. 2). The models were stored in a refrigerator for approximately 48 hours and subsequently thawed before the start of the experiments.

The cannula simulating a branch vessel was attached to a small silicone tube with an adjustable valve mechanism enabling a setting of variable outflow rates. Three different valve settings were used: fully closed; opened at 50%; and fully opened at 100% for creating antegrade outflow from the false lumen. Magnetic resonance imaging (MRI) measurements were performed (details are given below) at four equidistantly spaced locations (32 mm apart) and perpendicular to the aortic model: proximal to the dissection; at the beginning of the dissection; half way along the dissection; and distal to the dissection. A schematic representation of the models and measurement locations is presented in Fig. 2.

In model 1 data were acquired first with the valve fully closed, then opened at 50%, and then fully opened at 100%. For model 2, data were acquired with valve settings in reverse order, preventing a potential bias due to the duration of the experiment.

In vitro *circulatory system*

A validated *in vitro* circulatory system with physiological flow and pressure characteristics was used to simulate the human circulatory system.[10–12] The main components of this circulatory system are a pneumatically driven pulsatile pump with periodic triggering connecting to the MRI system for synchronization, simulating electrocardiogram (ECG) triggering; a compliance chamber; and a watertight synthetic box with the aortic dissection model (Fig. 3). All

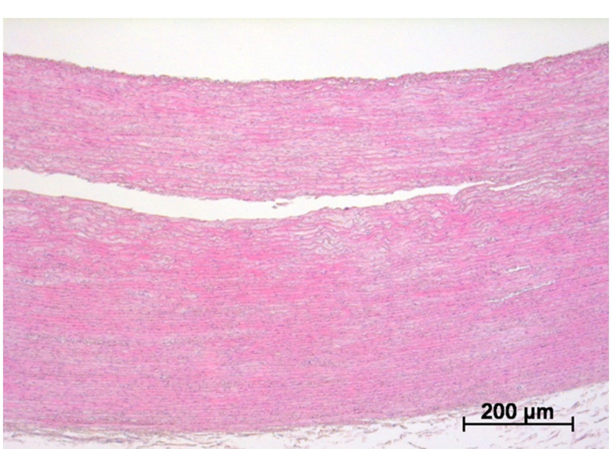

Figure 1. Microscopy after hematoxylin and eosin staining for the histological evaluation of the artificially created false lumen. The false lumen is created between intima with partial thickness media and partial thickness media with adventitia.

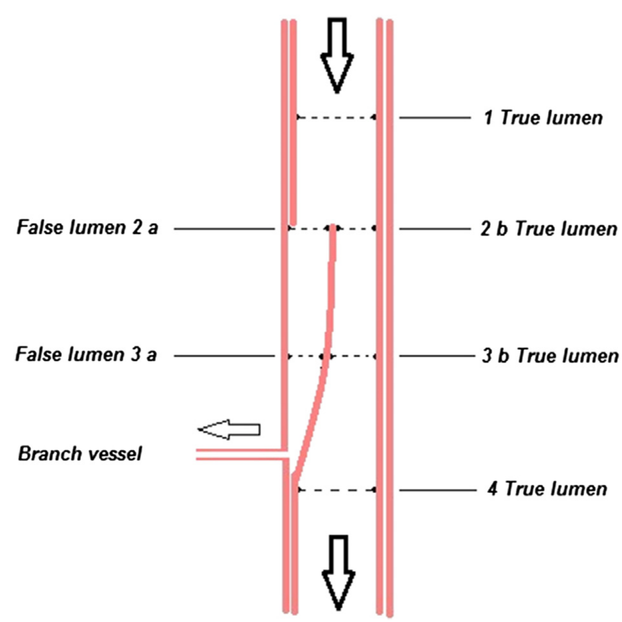

Figure 2. A schematic representation of the model. The four imaging planes are indicated and the arrows represent the flow direction.