there was a nice continuous distal aortic taper. But purely scientifically speaking, we have no control group and we can't prove for sure that there was no unusual growth of the distal aortic segment based on our study alone.

In terms of functional physiologic endothelial function proximal and distal to the stent, we did not perform any physiologic analysis. We did a very detailed histologic inspection of all specimens, and we compared the slaughter house healthy aortas to the segments that were taken from the aortic wall proximal and distal to the stent, and there really was no difference in wall thickness or architecture. But we don't know if there could have been a difference in endothelial function.

***Dr A. Haverich*** (*Hannover, Germany*): The diameter of the aorta between 37 kg piglets to 230 kg at the end of the experiment was less than 30% in growth. Wouldn't you think that if you would have started the experiment at the size of 20 kg that would have been the better idea? You could see the changes over time much easier, and you also would have been able to do both angiography and CT scan. I don't think the weight in kilogram is a good parameter for the size of the aorta.

***Dr Siegenthaler***: I think that is a very good idea. The problem with the piglets is that their aortas and peripheral vessels are extremely small compared to the total body size. I mean, it's very unexpected to have a 20 mm aorta for a 230 kg pig.

We have a size limitation in terms of how small we can go because the abdominal aorta in some of those piglets really just barely could fit the endovascular stent introduction system.

So probably we could have gone for five or maybe even 10 kg smaller animals, but at this point, the minimal possible size with a pig model will be reached.

***Dr J. Bachet*** (*Paris, France*): A stupid question from the moderator. You wanted to have endoleaks and you didn't. Couldn't you make a small hole in some grafts, in a few animals to be sure to get an endoleak and to survey it for 4 months?

***Dr Siegenthaler***: I am sure you could do something like that, but our goal was really to create a model for a type 1 endoleak and find methods of how to prevent aortic wall dilatation. That was the goal of the whole study. And interestingly enough, a conventional iliac covered stent already did the trick in preventing aortic growth, which we never expected.

## Editorial comment

# Performance of stentgrafts in growing arteries: there is demand for super-adaptable devices

The long-term impact of implanting stentgrafts on the behavior of growing arteries is still not fully understood. The ability of the aorta in its growing phase to react to and repair injuries induced by an implanted stentgraft makes this a unique and special area of research. Typically, a stented aortic segment containing either a bare stent or a stentgraft will develop stenosis, while the adjacent non-stented aortic segments grow and increase to their normal size and function as demonstrated by Siegenthaler et al. [1]. In clinical settings, stenting of aortic coarctation in adolescents usually requires redilation compensating for growth to avoid stenosis. Currently, the challenge facing stent and stentgraft design is the ability to adapt their geometries to the potentially large increase in the aortic dimensions over time.

In analyzing stentgraft performance in growing arteries, two key factors have to be considered; luminal area and wall thickness. First, the luminal area, and indeed not the diameter itself, is crucial for the aortic function in directly determining flow and should be used as the reference metric. The luminal area in a growing aorta is ultimately determined by the nominal area of the stentgraft minus the area of intimal hyperplasia. Stentgrafts have to be oversized by 10—20% to give sufficient frictional force to prevent migration at implantation. However, moderate oversizing might not be enough to match the ultimate adult aortic dimensions. By studying the performance of highly oversized self-expandable stentgrafts we noticed them compensating for some aortic luminal narrowing, thereby minimizing the effect of intimal hyperplasia [2]. Yet a moderate stenosis of 30—60% of the aortic area persisted. While high oversizing seems beneficial for the long-term performance of stentgrafts, they should have a minimal profile at implantation when constrained in a relatively small aorta. Highly oversized stentgrafts in a growing aorta can have folds of the fabric resulting in a large profile. We noticed that intimal hyperplasia optimizes flow characteristics by filling up folds creating a smooth circular lumen, yet the luminal area becomes smaller increasing the degree of stenosis. We do not yet know if these stentgrafts can fully expand to their nominal area by repeated dilations.

The second factor in the analysis of stentgraft incorporation in the context of growth is aortic wall thickness. While deploying a stengraft, blood is trapped between the device and the aorta, and the resulting clot becomes embedded with fibroblasts. This layer is commonly referred to as the interface, and can be substantial in the folds of the stentgraft fabric, while practically absent underlying the stent struts, which become embedded into the tunica media by the radial force of the stent itself and pulsation pressure. Within the stented area the thickness of the aortic wall is mainly composed of intimal hyperplasia including the protruding folds of the fabric with consecutive luminal narrowing. This underlines the importance of low profile devices. The fate of the tunica media underlying the device is currently unclear, yet medial thinning has been observed. Since the medial layer varies considerably, only measurements of its area are reliable. However, as long as the stentgraft remains implanted, the thickness of the media may well be irrelevant.

The experimental setting of aortic growth with its high reparative potential towards injury is not comparable to the clinical setting of dilatative arteriopathy in adult or elderly individuals, with their minimal capacity for integration of a stentgraft into the aortic wall. In the growing aorta, the interface itself, fixes and seals the device to the aortic wall, and in this context, the term endoleak should be avoided.

The study by Siegenthaler et al. supports the view that as endovascular surgery evolves, the interaction between relatively rigid stentgrafts and growing arteries should be a topic of further research in order to develop highly adaptable devices to ensure initial as well as sustainable long-term performance.

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