Chimneys, periscopes, snorkels (CHIMPS), chimney/periscope grafts and technical adjuncts (sandwiches) reflect the relentless and innovative approach to the endovascular treatment of complex aortic aneurysmal disease; the ultimate goal being the preservation of vital branch vessels from neck to groin. For those unfamiliar with the concept: the flow directionality of the conduit determines whether it is designated to be a chimney (pointing down and receiving flow from above) or a periscope (pointing up and receiving flow from below). The term ‘snorkel’ is used interchangeably with chimneys, given the imagery of the curved lower/distal end and the straighter upper/proximal end, and was actually proposed before the term ‘chimney’ became more widely adopted. The chimney or periscope then lies between the main body of the stent graft and the aortic wall at either the proximal or distal landing zone (or sandwiched between two bodies/extensions), thereby creating zones of potentially suboptimal conformation called ‘gutters’.

Endovascular aneurysm repair (EVAR) has come a long way and ten years after the first description of chimneys, chimney-EVAR (ChEVAR) has evolved considerably. In the beginning, many surgeons probably preferred to use balloon-expandable stent-grafts (e.g. the Advanta V12 or iCAST (Atrium, Midrecht, Netherlands)) as chimney/periscope grafts, based on the perception (possibly from fenestrated (F)EVAR practice) that a higher radial strength was required to maintain chimney/periscope patency, as well as achieve a better fit within the gutter. More recently, self-expanding stent grafts such as the Fluency (CR Bard Inc, Tempe, AZ, USA) and the Viabahn (WL Gore & Associates Inc., Medical Products Division, Flagstaff, Arizona, USA) have been increasingly used with success, and bare metal stents have also been used as single renal artery chimneys.

The main concerns about ChEVAR are whether they will be associated with a higher risk of difficult to treat type I endoleaks at the distal/proximal seals (otherwise known as gutter endoleaks) and reduced long-term visceral vessel patency. However, the intuitive assumption that gutter-associated type I endoleakage would be more common or more problematic (with endoleakage risk also perhaps arbitrarily perceived as increasing with the number of chimneys used) has now been refuted, particularly with growing awareness that it is probably less of a clinical problem than the classical high-flow type I endoleak. There are more subtle issues to be considered, however, as not all gutters are the same. Gutter endoleaks can be reduced by oversizing the main body (by up to 30–40% at the neck) and by using Viabahn stent grafts for the chimneys. The Viabahn is more compressible than the Atrium but still probably facilitates a better ‘wrap-around’ by the main stent graft body, thereby achieving a better seal around the gutter. Such bench studies (and it is not unreasonable to extrapolate these results to the in vivo scenario) have supported the shift away from balloon-expandable stent grafts towards self-expanding stent grafts as chimneys or periscopes. However, a recent report of post-ChEVAR ruptures cannot be ignored.

Two of nine patients who underwent single renal artery ChEVAR suffered from late abdominal aortic aneurysm rupture at 11 and 16 months, despite not having demonstrated any type la endoleaks in the previous surveillance scans; in fact, gutter endoleaks in two other patients had resolved spontaneously. Both patients who died had type la endoleaks, but what is not specified in the paper is the exact location of the endoleak, namely whether from the area of the gutter or elsewhere. What is highlighted though is the relevance of adverse neck anatomy (conical in these two cases) in the formation of these endoleaks, and perhaps the need for a more rigorous surveillance protocol, i.e. more frequent, and patient selection. This complication is rare in the literature, and, as the authors suggest, may indeed suggest the tendency in general for only positive results to be published.

The advantages of ChEVAR include not having to wait for a custom-made fenestrated stent graft device with its waiting time of 4–6 weeks (making it an attractive and immediate alternative in patients with a large AAA), the ability to use ‘off the shelf’ endovascular materials (perhaps less of an issue with the emergence of off-the-shelf fenestrated stent graft bodies), reduced costs and the avoidance of adjunctive interventions such as debranching procedures (e.g. subclavian-carotid-carotid bypass) or in situ fenestration to preserve the left subclavian artery during TEVAR.

Contemporary studies comparing early results between ChEVAR and FEVAR for juxtarenal aortic aneurysms (as part of a three-arm study also including open repair) indicate FEVAR (2465 vessels targeted) emerges with numerically better outcomes than ChEVAR (151 vessels targeted) for mortality (2.4% versus 3.2%, not statistically significant) and also renal dysfunction (9.8% versus 12%, though these were not statistically compared). Early proximal endoleakage was also lower in the FEVAR group (40/931), but only four of nine such endoleaks noted in the ChEVAR group needed...
treatment. Wilson et al.\(^3\) have recently performed a systematic review of outcomes from 24 studies where chimney/periscope grafts were deployed during ChEVAR for abdominal aortic aneurysm (AAA), thoracic aortic aneurysm (TAA) and thoracoabdominal aortic aneurysm (TAAA). In this systematic review, the immediate branch patency rate was 98.7% and the 30-day mortality was 5.1%. Seven vessels ultimately suffered branch vessel thrombosis (out of 376 stented vessels in 234 patients) to give a 98.1% branch patency at 12 months. The authors concluded that there was still insufficient medium or long term data, but this is not strictly accurate. Two-year follow-up has now been published on ChEVAR for complex AAAs, with a target vessel patency of 98%. Interestingly, most graft thromboses seem to occur early,\(^12\) suggesting a mechanical problem. One contributory factor to improved mid-term branch vessel patency might be because the Viabahn stent graft is the only one to be heparin-bonded. Similar outcomes have also been reported in the treatment of pararenal AAAs, with a midterm mortality of 0% and a 2.4% prevalence of type 1a endoleaks (two thirds of which required treatment).\(^13\) Acute kidney injury complicates about 6% of ChEVAR procedures,\(^3\) which compares favourably with the 1—19% incidence of acute kidney injury following conventional elective AAA-EVAR.\(^14\) An earlier systematic review looked specifically at aortic arch ChEVAR in 51 patients with single or double chimneys between 1994–2011. Here, the immediate technical success rate was about 90%, mortality was 5.9%, but 7.8% of patients suffered a peri-operative stroke. The type 1a endoleak rate was 11.8%.\(^15\) ChEVAR has also been successfully used in the treatment of dissection involving the aortic arch.\(^16\)

So where is ChEVAR heading? Work is currently underway to see whether gutters may be ‘tightened’ by endo-tacking them parallel to the chimney/periscope graft using the Aptus HeliFX device (Aptus Endosystems Inc., Sunnyvale, USA). It remains to be seen whether this reduces the rate of gutter endoleaks without compromising the chimney/periscope graft or target branch vessels. Innovative work from Lobato (founder of the sandwich approach\(^17\) including sandwiched CHIMPS), now permits ChEVAR to be performed from Ishimaru zone 0 to the groin. Full aortic arch outflow with 3-vessel sandwiched chimneys is now achievable and the same technique has been applied in TAAAs to achieve complete abdominal visceral perfusion with low morbidity and mortality. Whether there is still a need to select a large spinal artery for insertion of a chimney or periscope graft remains open to debate (as an alternative to temporary sac perfusion), given that preserving the left subclavian artery and the internal iliac arteries usually prevents spinal cord ischaemia. Internal iliac artery inflow can be achieved via ipsilateral deployment of a chimney\(^18\) (effectively replacing iliac branch grafts), or by an innovative crossover technique, whereby what actually starts as a periscope subsequently becomes a chimney.\(^19\)

Accordingly, there is now a possibility that ChEVAR enthusiasts may consider giving up FEVAR altogether. Only long term outcome data will resolve that issue. Will there ever be a prospective randomised controlled trial comparing the two? Unlikely. It is more probable that AAA- FEVAR will diminish in countries with an active screening programme as AAAs get picked up earlier with anatomy more conducive to conventional EVAR or ChEVAR. Branch vessel patency following ChEVAR appears to be good enough in the short to mid-term,\(^3,12\) compared to FEVAR (95.7% at one year, and 88.6% at 4 years).\(^21\) These data suggest that ChEVAR might become the preferred treatment option for juxta/pararenal AAAs; “a paradigm shift” indeed.\(^20\)

On the TAA front, chimney/periscope graft technology is well ahead of the fenestrated TEVAR SGs that are now entering the market and CHIMP techniques have found favour in the treatment of ruptured TAAA.\(^22\) Another area not yet explored is the potential for ChEVAR technology in lower limb aneurysms, especially in patients with popliteal artery aneurysms with no distal neck. Given the poor results associated with flow-modulator stents in this area,\(^23\) it might be preferable to insert chimneys into the crural vessels. In the context of branch vessel preservation, flow-modulator stent applications\(^24\) may challenge ChEVAR and FEVAR, but baseline costs (approximately £30,000 (€35420)) are currently prohibitive outside of any funded clinical trial.

As it currently stands, ChEVAR is here to stay. Many of the concerns about higher rates of complicated type I endoleaks and branch vessel occlusions have not materialised to the extent estimated and the technology is beginning to challenge other treatment strategies such as FEVAR and hybrid procedures. If future/long-term studies corroborate the positive short and mid-term data published to date, some of the other currently available endovascular strategies for treating complex aneurysms may go up in smoke!

**CONFLICT OF INTEREST**

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**REFERENCES**


