Carotid duplex ultrasound after carotid stenting

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Introduction

Duplex ultrasound (US) of the carotid arteries after carotid stenting is significantly different from the examination of an unoperated vessel or from the study following carotid endarterectomy.

The differences lie in the features examined and reported, but more importantly, in the criteria used to define carotid stenosis.

Nature of the scan

Generally, a follow-up scan after a carotid stenting procedure is performed for the surveillance of the stent, not for monitoring of the untreated contralateral carotid. Hence, if the contralateral carotid is not significantly stenosed, we perform ipsilateral scans only (i.e. “targeted US”).

Since the distal/cephalic end of the carotid stent can be placed well distal/cephalic to the point accessible at open carotid endarterectomy, Duplex US after carotid stenting often requires the use of a sector probe to visualise the distal end of the stent and the internal carotid artery (ICA) beyond it. This is particularly true in that one of the strong indications for carotid stenting (as opposed to endarterectomy) is the presence of a high carotid bifurcation, placing the distal end of the stent even closer to the skull base.

Finally, the timing of the scan in relationship to the date of the carotid stenting operation has an important bearing on the type of stenosis encountered.

Stenoses in the stented carotid artery

It is important to appreciate how “stenosis” is defined in the ICA and also the different “types” of stenoses encountered after carotid stenting, as well as their timing and their nature.

The landmark studies, NASCET1 and ECST2, used different definitions of carotid stenosis (Fig. 1); NASCET used the more logical distal, normal ICA as the denominator, whereas ECST used the diameter of the bulb. These were based of course, on angiographic assessments of stenosis. It is my practice when assessing in-stent stenosis with greyscale and colour US after carotid stenting to use the NASCET system – i.e. I compare the diameter of the most stenosed part of the stent to the diameter of the stent in a “normal” part of the ICA or the more distal ICA.

Fig. 2 illustrates the different types of stenoses encountered after carotid stenting, their timing and aetiology.

- Fig. 2a: This shows the “original carotid stenosis” requiring treatment.
- Fig. 2b: This shows the “completion residual stenosis” i.e. the residual stenosis still present at the end of the procedure on the final angiographic run. Note that in a carotid stenting procedure, we do not aim for angiographic perfection – this is not necessary for a good clinical outcome; furthermore, aggressive post stent dilation is the most dangerous part of the stenting procedure, the most likely to precipitate complications like stroke, profound bradycardia/hypotension or asystolic arrest. As a result, most interventionalists will allow residual stenoses of up to 50%, depending on circumstances.
- Fig. 2c: It is the nature of nitinol (a metal alloy of nickel and titanium with thermal memory) to continue expanding post deployment in the human body, with considerable radial force, often until it reaches the diameter of the tube of nitinol from which it was originally cut. Hence, a 7 mm nitinol stent will, over hours, days or months, gradually expand to 7 mm. It is both our experience...
with early post stenting Duplex US and also reported in the literature, that the “residual stenosis” on completion angiogram may considerably decrease in the coming days and weeks as the nitinol stent continues to expand. Hence, the “eventual residual stenosis” after carotid stenting may be considerably less than the “completion residual stenosis”.

- Fig. 2d: In the 6 weeks to 12 months following carotid stenting, the process of neo-intimal hyperplasia may gradually encroach within or even occlude the carotid stent, as occurs with stents placed anywhere in the body. The literature reports an incidence of significant carotid stent stenosis in the first two years post stenting of less than 10%, which compares favourably to carotid endarterectomy. In our own series, significant in-stent stenosis in the first two years post stenting is 4.5%.

- Fig. 2e: After 1–2 years, the neo-intimal hyperplasia process generally burns out (as with the body’s healing/scarring process everywhere). Nevertheless, it is to be anticipated that, in the long term follow up, carotid stents, like carotid endarterectomies, may undergo “late restenosis”. It is generally thought that this is caused by progression of the underlying disease, atherosclerosis. However, carotid stents have only been placed in large numbers in the last 10 years or so, (our series started in 2003), so true long term results are as yet limited.

Nature of the report

The following are the features a carotid scan in the post-stenting situation should address:

- The location of the carotid stent: Most typically, the carotid stent is placed from CCA-to-ICA. Less commonly, it may lie in the ICA only, CCA only, or rarely, CCA-to-ECA (Fig. 3). The reason for the placement of the stent across the bulb from CCA to ICA in most cases is for technical reasons at the time of stenting. The (typically) ICA origin stenosis needs to be reliably covered by the nitinol stent (to effectively “cage” the atheroma / atheromatous debris), and this is most safely done using only one stent. Hence, the interventionist will typically run a 4 cm length stent from normal CCA to normal ICA, covering the diseased bulb and ICA origin.

- Sampling of the stented carotid system: should be performed at the following locations: (Fig. 3).
  - 1: Mid / distal CCA before the stent (to establish inflow velocity).
  - 2: Proximal stent in CCA / bulb; often there is a significant increase in velocity at this point even though there may be no perceptible change in calibre of the vessel on greyscale or colour Doppler US. This is thought to be due to compliance mismatch between stented and unstented segment (see above).
  - 3: Stent in the proximal ICA, usually the site of the original stenosis and often the site of the most significant residual stenosis. This area may be harder to see as it is often associated with the heaviest calcification and ultrasound dropout.
  - 4: Most distal part of the stent in the ICA. Note that a stent can be, and often is, placed much higher (more cephalad) than a surgeon can perform a carotid endarterectomy. The distal end of the stent may therefore lie well beyond the carotid bifurcation – as a result, the sector probe to look high up under the jaw is often needed.
  - 5: The ICA immediately beyond the stent. As in post endarterectomy, this can be a site for problems and stenoses, though for different reasons. Carotid stents tend to straighten out the (not infrequently) tortuous vessels they are placed in and the bends in the vessel are forced cephalad by the stent. This may make the carotid beyond the stent less accessible and harder to examine. As above, the sector probe may be needed. Also, the end of the nitinol stent intersects with normal vessel, and is almost always larger than the native vessel (carotid stents, usually lying from CCA to ICA, are sized to the larger ICA); problems, such as dissection, can occur at this point.
  - 6: The ECA. As with open carotid endarterectomy, the ECA origin may be unchanged after intervention, may be more stenosed or less stenosed after intervention. In our own series of 150 carotid stenting procedures, in 16% the ECA stenosis was made significantly worse, in 7% it was made significantly better and in 77% it was unchanged. The ECA is clearly recognisable and distinguishable after carotid stenting as its origin is typically “crossed” by the stent (Fig. 4).

Defining stenoses post carotid stenting

Velocities

It has become well established that the various carotid stenosis criteria systems (e.g. Modified Zweibel University of Washington Duplex Criteria, ASUM) cannot be used when defining post carotid stenting stenoses. We became aware of this early in our carotid stenting program when we noticed that carotid stents, clearly seen and widely patent on grey scale and colour duplex, had velocities suggesting significant stenoses over 50%. The stented segment of the
A number of studies have looked at defining velocity criteria for significant stenoses post carotid stenting and they are given in Table 1. As a rule of thumb, only when systolic velocities exceed 200 cm/s should a significant stent stenosis be considered. It is our experience that these modified velocity criteria correlate much better with the colour and greyscale findings in the stented carotid.

**Colour and greyscale**
These modalities are useful in the unstented carotid, but even more so in the stented vessel. Firstly, the presence of the stent allows totally reliable distinction between ICA and ECA (provided the interventionist stented the correct vessel!). Greyscale clearly outlines the ICA, and an indentation in the stent is a hard and measurable sign of carotid stenosis. The converse is not true of course – a stent wide open on greyscale may in fact be compromised by neointimal hyperplasia and the flow channel could be quite narrow. Colour can also give a good reflection of stent patency, with colour fill to the edges of a usually clearly seen and well expanded stent indicating wide patency.

**Power angio**
This is a very useful tool in defining stent stenosis, particularly as it does not rely on velocity shifts. Set correctly, it can accurately define the stent flow channel in both longitudinal and transverse.

It is perhaps appropriate at this point to present the point of view of the carotid clinician/interventionist who personally performs large numbers of carotid Duplex scans, including post-carotid stenting scans. There is an over-reliance placed by sonographers and clinicians on carotid velocity numbers and criteria. Attempts are made at defining the degree of stenosis more accurately than they really can be or need to be. What the clinician wants to know is whether the carotid is 1) Widely patent or 2) Patent but with some stenosis or 3) Severely stenosed. Evidence in the field of carotid revascularisation supports the notion that we should only be treating severe stenoses, and mainly when they are symptomatic. Hence, lesions less than 80%, except when symptomatic are generally best left untreated; lesions less than 50%, even when symptomatic, should not be treated at all.

**Conclusions**
Colour Duplex scanning of the stented carotid system is different and in some way easier than scanning the unstented carotid vessels. The principles include careful assessment of the stent itself and the carotid vessels immediately before and after the stent in colour and greyscale. Most importantly, modified velocity criteria should be used in assessing the severity of the stenosis.

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