

Quantitative Imaging of Peripheral Nerves

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Rationale

A prototype neuroprosthetic walking assist system for footdrop (Neurostep™), recently implanted inside the thigh of a hemiplegic man, included two nerve cuffs placed on the common peroneal and tibial nerves and connected to a battery-powered pacemaker like control unit. Future neuroprosthetic devices may also enable paraplegic persons to stand up, transfer and sit down independently.

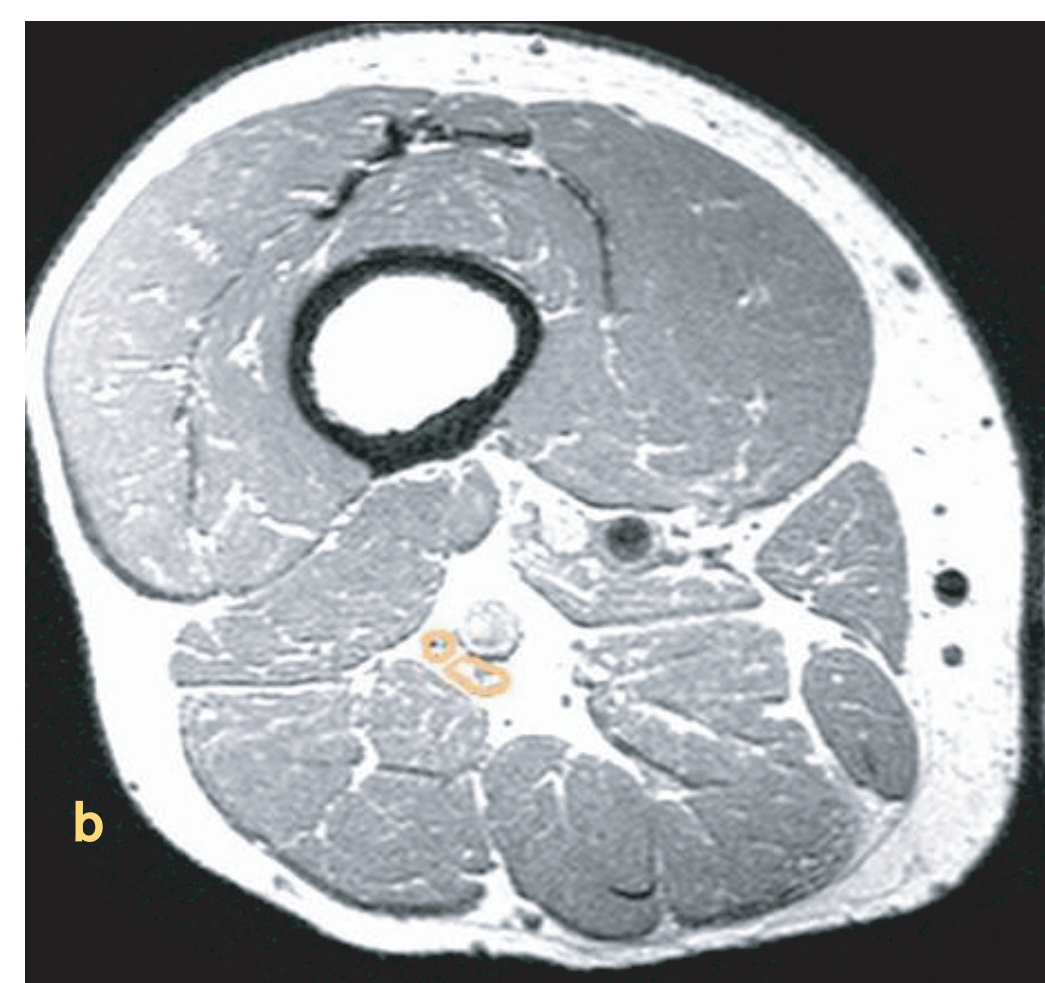
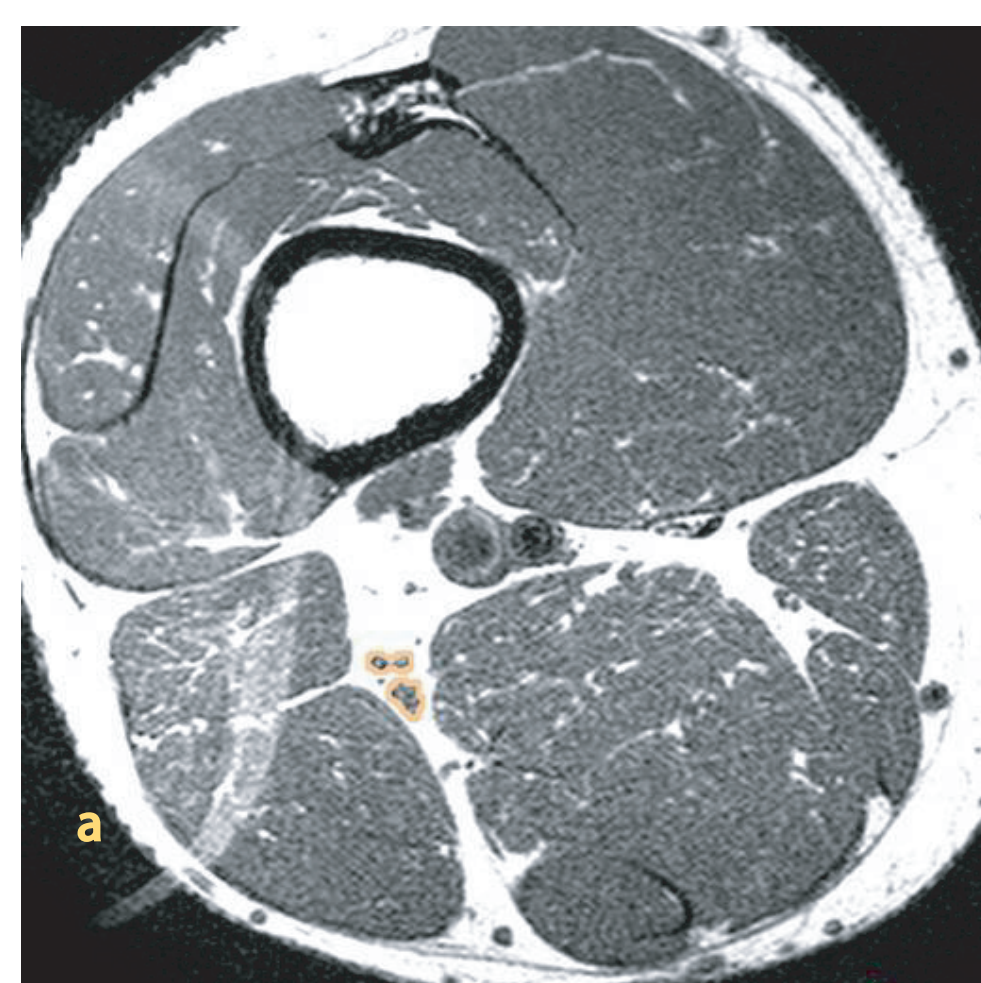
The surgical implantation of nerve cuff devices is straightforward, but can be complicated by considerable variability in target nerve branching pattern, size, location and local blood supply. This natural variability is further accentuated after central neurological lesions, as disuse atrophy affects not only paralyzed muscles but also their peripheral nerves.

Objectives

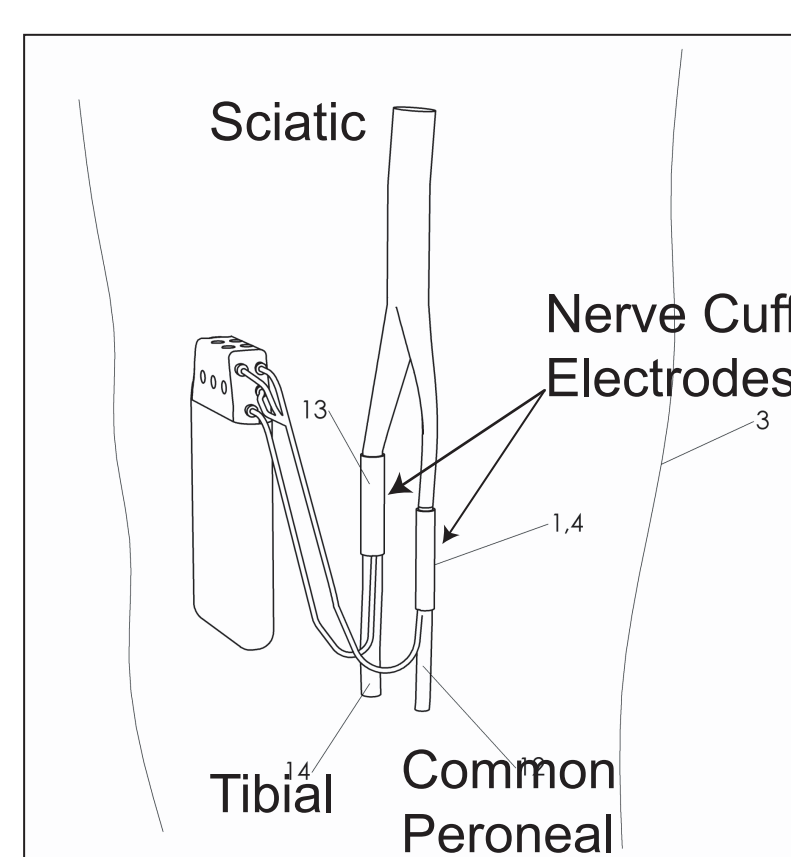
We are developing noninvasive, non-traumatic methods for obtaining and processing high-quality magnetic resonance images (MRI) of peripheral nerves in patients scheduled for neuroprosthetic implant surgery. Our goal is to precisely locate and measure each target peripheral nerve and its branches inside the limb.

Methods

We applied a two-tier imaging protocol optimization approach to pilot data from two subjects (JAH and MFB). An initial bilateral scan at coarse resolution provided a large field-of-view image of most of the thigh region. This allowed for visual identification of the region in the thigh where the sciatic nerve branches. Based on this identification, the second scan imaged a smaller region of the thigh containing the location of the sciatic nerve branch identified in the coarse scan. This second scan was acquired at higher resolution, typically 0.25 - 0.29 mm axial and 2 mm out-of-plane, imaged every 1 cm. Shown below are MR images from subjects MFB and JAH with the nerve branches outlined.

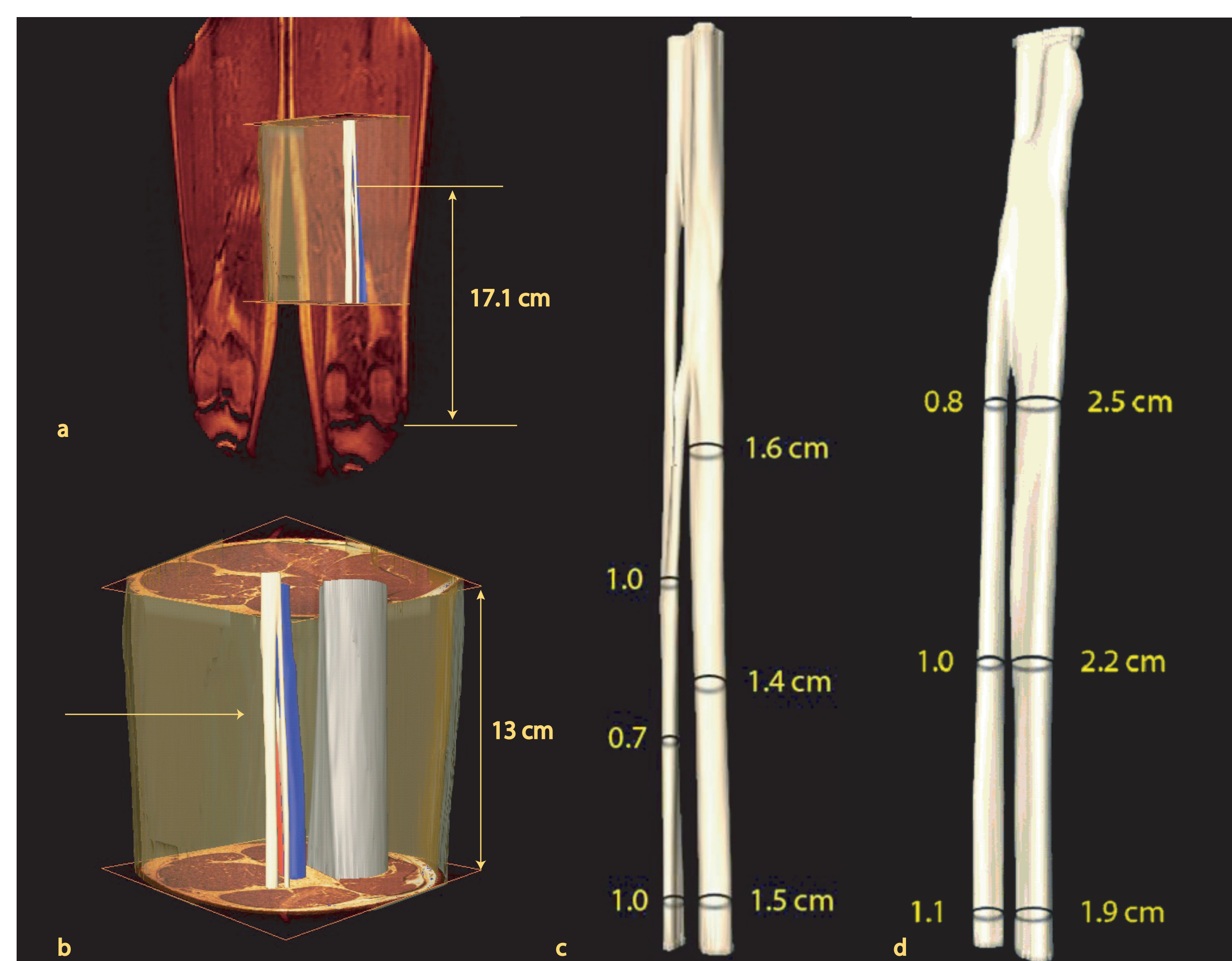


The axial slices from the higher resolution scans contain sufficient detail to identify the nerves of interest as well as anatomical structures such as the femur, femoral and popliteal arteries, saphenous vein, individual quadriceps and hamstring muscle heads, fat and skin layers. The perimeter and cross-sectional area of the reconstructed tibial and common peroneal nerve branches could be measured in the axial slices. Fourteen sequential slices were acquired along the thigh, spaced at 1 cm intervals to cover a 13 cm region of interest along the nerves, with the sciatic branch point located approximately midway. The data from these 14 axial slices was combined to create an accurate reconstruction of the internal thigh anatomy.



Preliminary Results

In the examples shown below, the high-resolution 3-D reconstruction image of a 13 cm long segment of the right thigh is shown superimposed on the low-resolution planar image of both thighs (a). The distance from a bony landmark (distal end of the internal condyle of the femur) to the point at which the sciatic nerve naturally divides into its common peroneal and tibial branches in the right thigh was measured to be 17.1 cm. Part (b) shows in greater detail the level at which the sciatic nerve was seen to split into its branches (arrow). Part (c) and (d) show the computed perimeter for the common peroneal and tibial nerve branches, measured at three different levels in two subjects (MFB, JAH). Note the double bifurcation of the sciatic seen in (c) compared to the pattern seen in (d).



Anticipated Benefits

1. Provide currently unavailable, quantitative data on: a) the natural variability in location of the sciatic nerve branch point, b) extent of bilateral symmetry in sciatic nerve branch point location, c) sciatic, tibial and common peroneal nerve sizes in control subjects and d) quantitative measurements of flexor and extensor nerve atrophy in subjects with spinal cord injury.

2. Provide high-quality 3D images of nerves in patients scheduled for neuroprosthetic implants or other peripheral surgery. Prior knowledge of the exact location and pattern of branching is likely to lead to shorter surgical times, shorter surgical incisions and less likelihood of trauma to nerves and surrounding tissues.

Reference

Initial results with fully implanted Neurostep™ FES system for foot drop
Hoffer JA, Baru M, Bedard S, Calderon E, Desmoulin G, Dhawan P, Jenne G, Kerr J, Whittaker M, Zwimpfer TJ (2005).
http://www.ifess.org/cdrom_target/ifess05/Special%20Session%204/Hoffer%20JA.pdf