Perfusion CT for Assessment of en bloc Implant Vascular Success

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Introduction: A current limitation to the success of many tissue-engineered scaffolds may be attributed, at least in part, to failure of an early competent vascular supply. Perfusion CT is an imaging modality used in stroke and tumor assessment\(^1\), and it may also be suitable for the evaluation of en bloc implants in small animal models for the purpose of evaluating implant success. Perfusion CT is capable of providing quantifiable in vivo information including blood flow (BF), blood volume (BV), mean transit time and permeability surface. Our aim is to demonstrate the feasibility of a clinical CT scanner for evaluating tissue engineered implants directed towards an early vascular supply within musculoskeletal defects.

Methods: Muscle tissue (123+/−11mg, ~30% mass) was removed from both tibialis anterior muscles of adult male Lewis rats. Defects were either not repaired (NR; n=1) or received a collagen implant (COL; n=2) or collagen implant containing microvascular fragments (MVF; n=3) as a positive control. Two weeks after surgery, a time when MVF integration within muscle has been demonstrated histologically, both legs were imaged. A Styrofoam fabricated device ensured proper anatomic alignment while scanned on a Toshiba 64 Aquilion CT at 80 kVp and average 270 mAs using 1 sec cine scanning at 1 sec intervals for 64 secs, followed by 15 sec intervals for a total scan time of 274 secs. Omnipaque 300 was injected via tail vein catheter 5 secs after scan initiation for tissue contrast. A second perfusion scan was obtained 24 hours later with percutaneous electrode nerve coupled stimulation of anterior tibialis muscles; a procedure shown to predictably increase anterior tibialis muscle flow on Perfusion CT. Images were reconstructed using a soft tissue filter with slice thickness of 0.5 mm and voxel size of 0.234 mm. Post-processing of images in Strok too tool CT was performed with subsequent blood flow and blood volume perfusion maps rendered in MIPAV for volume of interest analysis. Statistical differences were determined using a student’s t-test.

Results: MVF implants were discretely visualized on resting imaging 2 weeks after surgery, and occupied a mean volume of 82.7±7.4 cc with BF and BV of (mean ± s.d.) 106.2±23.8 cc/min/100cc and 72.5±20.9 cc/100cc. Control (NR and COL) implants were not discretely visualized limiting subsequent analysis; however, superficial areas of increased flow occupying a mean volume 58.7±15.6 cc (p = .06) were present and used as comparison with BF and BV of 65.9±7.4 cc/min/100cc (p = .04) and 42.0±15.3 cc/100cc (p=.11). Interpretation and analysis of stimulated imaging performed 24 hours later is ongoing.

Discussion and Conclusions: Assessing functional vasculature is integral to directing strategies aimed at overcoming current en bloc implant limitations. Perfusion CT is a validated\(^1\) imaging modality that can easily be obtained at the time of terminal procedures, providing in vivo functional assessments supplemental to histological analyses. The spatial resolution of clinical CT scanners is adequate in small animal models\(^2\) with the aim of perfusion imaging not to detail capillary architecture, but provide end tissue perfusion as demonstrated in Figure 1. These data both demonstrate the feasibility of clinical CT for assessing in vivo perfusion in small en bloc implants and that MVF seeded collagen provides space occupying perfusible vascularity not seen in controls. Non-discrete areas of perfusion among controls are presumably inflammatory changes rather than implant integrity. Clinical CT imaging allows fast quantifiable assessment of perfusion in regenerating tissues and may be a valuable tool to assess the effect of various tissue engineering approaches on angiogenesis.

References:

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