In Response:

Thank you very much for your response to this article. Your statements regarding "blind" palpation based lumbar punctures versus image guided approach as well as discussing the alternative to direct measurements in flight are appreciated. Many of the statements that you have made are valid. Are astronauts usually of more "sporty" build than a typical patient? Absolutely. Is experience and training irreplaceable? Agreed. Is it possible that with enough training and experience and given the sporty nature of astronauts, that performing a blind approach lumbar puncture in microgravity could be accomplished with high likelihood of technical success? Completely. Many of the things you mentioned I already include in my lectures on this subject. The origin of this research was based on informal discussions with people at the Johnson Space Center, Houston, TX, about this topic. One of the questions was: If a lumbar puncture (LP) was indeed desired in flight, would there be a way to perform it with imaging to allow remote confirmation and guidance of the procedure via communication with experts on the ground in a stepwise process. Specifically, could direct guidance be performed with ultrasound since it is currently the only imaging modality on the International Space Station. The purpose of this research was to provide an answer to those questions via a proof of concept, and we feel we have succeeded in that goal. Regarding the discussion of whether or not in-flight LP should performed at all was not the

aim. The actual decision whether to perform an LP in flight is an operational question beyond the scope of our paper. Due to the numerous changes that occur in microgravity, including alterations of bone, ligaments, blood vessels and intervertebral disks, as well as potentially the spinal cord, conus location, and cauda equina, the standard approach may be distorted and incur additional risk.^{1,2} We consider it safer to use a guided approach using the versatile technique we demonstrated in our paper.

Making a case for or against performing in-flight LP was not the intent of this article, but to provide a potential way to perform such a procedure if remote direction and imaging guidance was indeed desired.

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