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CORRESPONDENCE

Rebuttal letter in response to Professor R.H. Anderson's letter 'Evolution of the vertebrate heart'

We read with attention the letter of Emeritus Professor R. H. Anderson with regard to our review recently published in *Journal of Anatomy* (Stephenson et al. 2017).

With regard to the fact that we focused only on the 'normal' heart, bypassing the 'abnormal heart', we feel that arguing that there are anatomical cardiac morphological differences based on pathology is well beyond the goal and the purposes of our review. The above concept can be applied about every aspect of anatomy and physiology, covering an extremely vast topic. Our review was discussing general evolution, not every single pathology along its billion-year journey. You cannot include every single thing written on the subject. We feel that our content is well tailored for a 'normal' anatomy view of the field (as well as for the kind of journal where we published our review).

We were somewhat surprised by the fact that the main criticism of our review was based on papers not yet available at the time of writing and published after the acceptance of our paper (MacIver et al. 2018a,b). Emeritus Prof. Anderson confutes the existence of the so-called helical ventricular myocardial band (HMVB) introduced by Torrent-Guasp (Torrent-Guasp et al. 2005; Kocica et al. 2006) in the mentioned reviews not available at the time of our paper assembly and acceptance.

Of note, the model of heart anatomy based on the HVMB has been validated in several aspects of heart pathophysiology and it is involved in clinical understanding and clinical procedures in cardiology and heart surgery, such as heart failure (Buckberg et al. 2015a,b; Buckberg, 2016). Furthermore, the model has been mentioned in classic (and widely used) anatomy textbooks (Moore et al. 2013, 2018) and substantiated in electromechanical computing models (Marcé-Nogué et al. 2013). As a model, the HMVB does not have to be correct to be useful, but it has to be functional and effective within certain boundaries. Quoting Claude Bernard "Anatomists 'deduce' to explain Physiology. While Physiologists 'explain it' by anatomy" (Bernard, 1957) is sometimes difficult and probably confounding when trying to conceive a straightforward structure–function relationship from what do you see in a given experimental procedure (the history of the heart anatomy and this debate are a perfect demonstration of this concept).

We agree that the HVMB is probably more a gross anatomy/functional anatomy view of the heart and not a model that includes careful histology and microscopic anatomy, but its value cannot be undervalued in understanding cardiac pathophysiology. Every model in science is a representation of the reality (not necessarily the reality itself) and it is a continuum, where new discoveries and new research techniques shape, change and confute the model. HVMB does not escape this trend.

The various techniques of imaging used in the field to understand ventricular cardiac shape *in vivo* still have a many shortages and caveats, before leading to definitive and convincing results; of course it is difficult (or not yet possible) to obtain 3D data from living embryonic heart and living adult hearts that integrate histology, contraction, morphology and cell tracking techniques. New innovative techniques are promising (Tomer et al. 2014; Li et al. 2016; He et al. 2017; Hsueh et al. 2017) but we have not yet reached the critical point of applying robustly these techniques in a living organ. The proposed alternative models by the Anderson group ('a continuous 3D meshwork', MacIver et al. 2018a) or the 'nested layers' structure proposed by Hoffman (Hoffman, 2017) have good potential and '*raison d' etre*', but we feel that the HVMB is still a viable and useful model and that the various proposed alternative models could be complementary rather than contradictory. In this regard it is noteworthy that MacIver et al. (2018b) in their review on clinical and functional aspect of their heart morphology model state: 'it is immediately apparent that functional differences between the two models are not as marked as their anatomical variation. This explains why the differing concepts can continue to have their separate devotees…'.

In conclusion we acknowledge the substantial contribution of Emeritus Prof. Anderson and his acolytes to the field, but at the same time we feel that the HVMB model still stands despite its own limitations and that we are not yet at the end of the HVMB saga: more studies are needed to better delineate the structural and functional anatomy of the heart and ultimately validate the various proposed models.

Conflict of interest

None reported.

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References

Bernard C (1957) *An Introduction to the Study of Experimental Medicine*. New York: Dover Publications (originally published in 1865).

Buckberg GD (2016) Echogenic zone in mid-septum: its structure/function relationship. *Echocardiography* **33**, 1450–1456.

Buckberg GD, Hoffman JI, Coghlan HC, et al. (2015a) Ventricular structure-function relations in health and disease: part I. The normal heart. *Eur J Cardiothorac Surg* **47**, 587–601.

Buckberg GD, Hoffman JI, Coghlan HC, et al. (2015b) Ventricular structure-function relations in health and disease: part II. Clinical considerations. *Eur J Cardiothorac Surg* **47**, 778–787.

He L, Li Y, Pu W, et al. (2017) Enhancing the precision of genetic lineage tracing using dual recombinases. *Nat Med* **23**, 1488–1498.

Hoffman JI (2017) Will the real ventricular architecture please stand up? *Physiol Rep* **5**, e13404.

Hsueh B, Burns VM, Pauerstein P, et al. (2017) Pathways to clinical CLARITY: volumetric analysis of irregular, soft, and heterogeneous tissues in development and disease. *Sci Rep* **7**, 5899.

Kocica MJ, Corno AF, Carreras-Costa F, et al. (2006) The helical ventricular myocardial band: global, three-dimensional, functional architecture of the ventricular myocardium. *Eur J Cardiothorac Surg* **29**(Suppl 1), S21–S40.

Li YC, Zhang YS, Akpek A, et al. (2016) 4D bioprinting: the next-generation technology for biofabrication enabled by stimuli-responsive materials. *Biofabrication* **9**, 012001.

MacIver DH, Stephenson RS, Jensen B, et al. (2018a) The end of the unique myocardial band: part I. Anatomical considerations. *Eur J Cardiothorac Surg* **53**, 112–119.

MacIver DH, Partridge JB, Agger P, et al. (2018b) The end of the unique myocardial band: part II. Clinical and functional considerations. *Eur J Cardiothorac Surg* **53**, 120–128.

Marcé-Nogué J, Fortuny G, Ballester-Rodés M, et al. (2013) Computational modeling of electromechanical propagation in the helical ventricular anatomy of the heart. *Comput Biol Med* **43**, 1698–1703.

Moore KD, Dalley AF, Agur AMR (2013) *Clinically Oriented Anatomy*, 7th edn. Philadephia: Lippincott Williams & Wilkins.

Moore KD, Dalley AF, Agur AMR (2018) *Clinically Oriented Anatomy*, 8th edn. Philadelphia: Lippincott Williams & Wilkins.

Stephenson A, Adams JW, Vaccarezza M (2017) The vertebrate heart: an evolutionary perspective. *J Anat* **231**, 787–797.

Tomer R, Ye L, Hsueh B, et al. (2014) Advanced CLARITY for rapid and high-resolution imaging of intact tissues. *Nat Protoc* **9**, 1682–1697.

Torrent-Guasp F, Kocica MJ, Corno AF, et al. (2005) Towards new understanding of the heart structure and function. *Eur J Cardiothorac Surg* **27**, 191–201.