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**Maclver, DH, Partridge, J, Agger, P, Stephenson, RS, Boukens, BJD, Omann, C, Jarvis, JC and Zhang, H**

**The end of the unique myocardial band: Part I. Anatomical considerations**

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### Article

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1 **Title page:**

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3 **considerations**

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44

45 **Abstract**

46 The concept of the “unique myocardial band”, which proposes that the ventricular  
47 myocardial cone is arranged like skeletal muscle, provides an attractive framework for  
48 understanding hemodynamics. The original idea was developed by Francisco Torrent-Guasp.  
49 Using boiled hearts and blunt dissection, he created a single band of ventricular  
50 myocardium extending from the pulmonary trunk to the aortic root, with the band thus  
51 constructed encircling both ventricular cavities. Cooked hearts can, however, be dissected  
52 many ways. In this review, we show the band does not exist as an anatomical entity with  
53 defined borders. On the contrary, the ventricular cardiomyocytes are aggregated end-to-  
54 end, and by their branching produce an intricate meshwork. Across the thickness of the left  
55 ventricular wall, the chains of cardiomyocytes exhibit a gradually changing helical angle,  
56 with a circumferential zone formed in the middle. There is no abrupt change in helical angle,  
57 as could be expected if the wall was constructed of opposing limbs of a single wrapped  
58 band. Nor does the long axis of the cardiomyocytes consistently match with the long axis of  
59 the unique myocardial band. There are, furthermore, no connective tissue structures which  
60 could be considered to demarcate its purported boundaries. The unique myocardial band  
61 should be consistent with evolution, and while the ventricular wall of fishes and reptiles  
62 have one or several distinct layers, a single band is not found. In 1965, Lev and Simpkins  
63 cautioned that the ventricular muscle mass of a cooked heart can be dissected almost at the  
64 whim of the anatomist. We suggest the unique myocardial band should have ended there.

65

66 Key words: Helical ventricular myocardial band; Helical heart; Ventricular anatomy; Cardiac  
67 CT; Histology; Echocardiography; Embryology; Comparative anatomy

68

## 69 **Introduction**

70 An accurate description of the architectural arrangement of the cardiomyocytes making up  
71 the walls of the left ventricle is fundamental to the understanding of myocardial function.  
72 Ventricular mural anatomy has been extensively studied over the last 400 years, but debate  
73 continues regarding the precise pattern of the architectural arrangement of the  
74 cardiomyocytes aggregated together within the walls. Amongst various models, an  
75 intriguing concept was introduced by Torrent-Guasp.[1] He postulated the existence of a  
76 “unique myocardial band”, or “helical ventricular myocardial band”, which was wrapped in  
77 such a way as to produce a “helical heart”. [2] The concept has since been developed by  
78 some so as to provide explanations for many aspects of surgical cardiac disease,[3-5] even  
79 being cited recently to explain the actions of cardioplegia.[6] None of these multiple  
80 publications, however, including the initial studies of Torrent-Guasp, have been validated by  
81 histological studies. In contrast, there is a wealth of anatomical evidence, including multiple  
82 histological investigations, which demonstrates the cardiomyocytes to be aggregated  
83 together to form a three-dimensional mesh. This arrangement is much more complex than  
84 the structure envisaged by proponents of the “unique myocardial band”. Here we review  
85 the anatomy of the ventricular mass so as to demonstrates the multiple shortcomings of the  
86 concept of a unique myocardial band. In an accompanying paper, we review several lines of  
87 evidence from physiology which, like the present paper, do not lend support for the notion  
88 of the unique myocardial band.

## 89 **The beginning of the “unique myocardial band”**

90 Based on gross dissections, Torrent-Guasp proposed that the walls of the right and left  
91 ventricles exist as a continuous myocardial band, which extends from the root of the  
92 pulmonary trunk to the root of the aorta.[1] The muscular band thus sculpted from the  
93 ventricular mass was held to form two loops, which surround the cavities of both right and  
94 left ventricles. The first, or basal, loop commences at the pulmonary valve, and consists of  
95 the right ventricular free wall. It leads to the outer layer of the left ventricular free wall, and  
96 thence on to to the right ventricular side of the ventricular septum. The band then  
97 continues as the second, or apical, loop, which has a descending segment comprising of the  
98 inner left ventricular free wall, and an ascending segment. The latter segment then forms

99 the sub-epicardial component of the apex and the rightward component of the ventricular  
100 septum, terminating at the aortic root. The cardiomyocytes aggregated together within the  
101 band were held to be aligned along its long axis, so that the ascending and descending  
102 segments crossed in approximately perpendicular fashion within the septum. Cleavage  
103 planes, or sliding surfaces between the segments, were alleged to exist, thus allowing the  
104 parts of the band to move across one another. The purported physiological consequences of  
105 this arrangement were subsequently described in numerous publications, [5, 6] including an  
106 account of cardiac development.[7]

### 107 **The dissection process used to create the "unique myocardial band"**

108 Torrent-Guasp developed his technique of dissection over a period of 25 years.[1, 3] The  
109 hearts were boiled for a prolonged period, softening the myocardium so as to permit  
110 subsequent dissection.[6] The anterior free wall of the right ventricle, along the anterior  
111 interventricular groove, was prised off the ventricular septum, using the thumb to cut  
112 through the cardiomyocyte aggregates and connective tissues. The pulmonary trunk was  
113 thus detached from the root of the aorta, with the blunt dissection extended to the apex of  
114 the right ventricle to open the right ventricular cavity. At the inferior limit of the right  
115 ventricular cavity, at the junction of the right ventricular free wall and ventricular septum,  
116 the blunt dissection was continued into the mid zone of the left ventricular wall, and on  
117 towards the root of the aorta, thus exposing the inner helical zone. The left fibrous trigone  
118 was cut, permitting creation of a plane in the middle of ventricular septum. The dissection  
119 was continued between the inner and outer helical zones, followed by cutting the right  
120 fibrous trigone and freeing the aorta. Unfolding the dissection thus created an allegedly  
121 unique myocardial band, extending from the pulmonary trunk to the aortic root. This  
122 concept of a continuous myocardial band, with attachments at the arterial roots, is  
123 attractive, since it permits direct comparison with skeletal muscles, whose myocyte  
124 aggregates do indeed run between points of origin and insertion formed by connective  
125 tissue or bony structures. Most skeletal muscles, however, are enclosed in fibrous sheaths,  
126 thus permitting their dissection along identifiable boundaries. As has been emphasized  
127 previously,[7] this is not the case for the ventricular myocardial cone.

## 128 **Histological and anatomical perspectives**

129 The essence of skeletal muscles is that the extent of each entity can readily be revealed by  
130 anatomic dissection. None of the histological studies of the myocardium of which we are  
131 aware, in contrast, has provided any evidence for an origin and insertion as described for  
132 the alleged unique myocardial band. [8, 9] Already in 1864, Pettigrew had emphasised that  
133 the myocardial mass was not arranged like skeletal muscle, instead describing the  
134 arrangement of cardiomyocytes within the ventricles as aggregated to form multiple  
135 interleaving sheets.[10] Nearly 40 years later, Krehl showed how some of the  
136 cardiomyocytes were aligned in circumferential fashion within the middle zone of the left  
137 ventricular walls.[11] These histological findings were subsequently confirmed by Feneis, [8]  
138 and by Greenbaum and colleagues.[12] Dissection of the left ventricle shows the gradual  
139 transition in the myocardial grain between the inner, middle and outer zones (Figure 1).[13]  
140 Sanchez-Quintana and associates were able to show the presence of the circumferential  
141 cardiomyocytes in human hearts using anatomical dissection ([Figure 2](#)).[14] LeGrice and his  
142 associates subsequently showed how the cardiomyocytes themselves were aggregated  
143 together in sheet-like configurations.[15] These aggregated entities, or lamellar units,  
144 however, do not extend across the ventricular wall, as was suggested by the diagrammatic  
145 depiction originally provided by LeGrice and his colleagues [15]. Instead, the aggregated  
146 cardiomyocytes throughout the ventricular walls are bound together both by their meshed  
147 branching, and by the endomysial component of the fibrous matrix, being separated by  
148 spaces containing loose perimysial tissue, arteries and veins.[16] This arrangement,  
149 validated by histology, is incompatible with the concept of the “unique myocardial band”.  
150 The intercellular spaces and myocytic branches are ubiquitous within the walls, failing to  
151 provide the boundaries needed to produce an anatomically discrete myocardial band.

152 Although providing no evidence to validate the notion of the unique myocardial band, the  
153 histological evidence does support the presence of helically arranged chains of aggregated  
154 cardiomyocytes. Indeed, a well-recognised study had long since demonstrated the  
155 progression of such helical angulations when traced through the thickness of the left  
156 ventricular walls.[17] The arrangement is that of a left-handed outer helix, with negative  
157 angulation relative to the ventricular equator, progressing through a region of zero

158 angulation at the midwall, and continuing as a right-handed helix, with positive angulation,  
159 towards the inner endocardial ventricular surface.[17] This gradual change in helical  
160 angulation exists in all the regions of the ventricular walls, including the ventricular  
161 septum.[17] In the initial study [17], all the cardiomyocytes, despite their change in helical  
162 angulation, were reported to be aligned in more-or-less tangential fashion when assessed  
163 relative to the epicardial ventricular surface. Subsequent histological investigations, which  
164 used circular knives to cut tissue blocks from the ventricular walls, thereby cancelling the  
165 effect of the helical angle on the orientation of the cardiomyocytes within the sections  
166 transferred to the microscope slides, revealed that significant numbers of cardiomyocytes  
167 deviated from the tangential plane.[18, 19] Investigations using pneumatic dissection of the  
168 ventricular walls [20] then showed how it was possible to disrupt the weaker perimysial  
169 component of the fibrous matrix. These manoeuvres confirmed that the cardiomyocytes  
170 were aggregated together to form an intricate three-dimensional meshwork. Histological  
171 findings, therefore, provide further evidence of a complex mural ventricular structure  
172 (Figure 3). None of these investigations has provided any evidence of an alignment of the  
173 cardiomyocytes that follows the course of the unique myocardial band. All of the studies, in  
174 contrast, have shown a relatively uniform pattern of aggregation throughout the ventricular  
175 circumference.[8] The only study of which we are aware to have produced the band by  
176 following the directions of Torrent-Guasp,[1] [2] and then sectioning it histologically, failed  
177 to find correlation between the long axes of the band and its contained cardiomyocytes.[21]

### 178 High resolution computer tomography

179

180 Recent advances in microcomputed tomography, using iodine enhancement of myocytic  
181 and vascular structures, have provided images of sufficient spatial resolution to reveal the  
182 alignment (Figure 4) and dimensions of the chains of individual cardiomyocytes (Figure 5),  
183 along with the pattern of the units produced in consequence of their aggregation within the  
184 endomysial weave of the supporting fibrous matrix.[16, 22, 23] (Figure 5). ~~They~~ The CT  
185 images (Figure 5) confirm the presence of the chevron-like configurations revealed  
186 histologically (Figure 3), which exist within the setting of a relatively smooth helical  
187 transmural arrangement (Figure 3,4 & 5). ~~They~~ These images fail to reveal the abrupt



188 changes in angulation at the midwall that would be expected were the ventricular cone  
189 based on the postulated wrapped myocardial band ([Figure 4 & 5](#)). Instead, they support the  
190 notion of the complex mural mesh, with units exhibiting both helical and transmural angles,  
191 complex heterogeneous morphologies, and multiple connections to adjacent units via  
192 myocytic chains (~~Figure 4~~).[16]

### 193 **Embryological perspective**

194 The ontogenetic development of the human heart is complicated. In a review that sought to  
195 correlate development with the notion of the helical heart, we were asked to envisage that  
196 “a simple and integrated triple figure-eight spiral band, with three S-shaped helixes and  
197 their apices may correlate the conventional embryologic development of the primitive heart  
198 (bulbus cordis, ventricle, and arterial outflow vessels)”.[7] Much has been learned regarding  
199 cardiac development since the publication of this review. We now know that the original  
200 linear heart tube forms little more than the definitive left ventricle.[24] New material is  
201 added at the arterial pole from the heart-forming areas to form the right ventricle and the  
202 outflow tract. Similar new growth at the venous pole produces the atrial chambers and the  
203 veno-atrial connections.[25] In terms of development of the ventricular mass, initially the  
204 walls are made up predominantly of a meshwork of luminal trabeculations, with minimal  
205 formation of a compact layer. At the early stages of development, subsequent to looping of  
206 the heart tube, the atrial chambers connect to the developing left ventricle, while the  
207 outflow tract is supported above the developing right ventricle. Rightward expansion of the  
208 atrioventricular canal then brings the right atrial cavity into communication with the cavity  
209 of the right ventricle.[26] After this process, which occurs during the twelfth day of  
210 development in the mouse, the developing outflow tract, which is beginning its separation  
211 into the aortic and pulmonary roots, remains supported by the developing right ventricle,  
212 The left ventricle at this stage, therefore, connects to the developing aortic root through the  
213 embryonic interventricular communication. It is only subsequent to transfer of the aortic  
214 root to the left ventricle that there is closure of the interventricular communication. Even at  
215 this stage, which has occurred by the fourteenth day of murine development, there has  
216 been minimal growth of the compact layers of the ventricular walls. The rate of proliferation  
217 of the compact myocardium, and the compact component of the ventricular septum, is

218 known at this stage to exceed that of the trabeculated myocardium.[27, 28] Beginning at  
219 this stage, it is then possible to recognise the aggregation of the individual cardiomyocytes  
220 into units of various shapes and dimensions, with the units separated by perimysial spaces  
221 throughout the circumference of the walls. When assessed in long axis, many of the units  
222 show the sheet-like configuration emphasised by LeGrice and his colleagues, although none  
223 of the aggregated units extend in full transmural fashion (Figure 6A). When assessed relative  
224 to the short axis of the ventricular cone, the aggregates show an obvious circumferential  
225 arrangement in the middle component of the wall, with the parietal left ventricular  
226 aggregates extending into the ventricular septum (Figure 6B). The perimysial spaces are not  
227 positioned in such a way as to permit unwrapping of the alleged myocardial band. On the  
228 contrary, the overall arrangement of the walls is very much that of a complex three-  
229 dimensional mesh. Molecular identification of the compact wall and ventricular septum,  
230 besides being possible using proliferation markers, can also be made based on expression of  
231 *Hey2* and *N-myc*. [29] *CHF1/Hey2* plays a pivotal role in left ventricular maturation through  
232 suppression of ectopic atrial gene expression. [29, 30] Neither of these genes, nor indications  
233 of proliferation by *BrdU* incorporation or expression of *Ki-67* and *PCNA*, [25, 30, 31] give any  
234 indication of distinct bands in the compact wall compatible with the postulated helical  
235 heart. A recent developmental study, furthermore, suggested the anterior ventricular  
236 septum to be formed from a merger between the embryonic left ventricle and the outflow  
237 tract. [32] This arrangement provides no support for the opening of the ventricular wall in  
238 the manner of Torrent-Guasp.

### 239 **Comparative anatomical perspective**

240 It has been suggested that the unique myocardial band is compatible with the overall trends  
241 of evolution of the heart. [7] Mammals evolved from ectothermic (cold-blooded)  
242 vertebrates, but the orientation of cardiomyocytes in these species has received limited  
243 attention. [33, 34] We do know that, in some fishes and most amphibians, the compact wall  
244 may be so thin that the epicardium almost touches the ventricular lumen. In this setting, the  
245 compact wall consists of one layer only (Figure 7). In some highly active animals, like tuna  
246 fish, in contrast, the compact wall is well developed, and may consist of two or three layers.  
247 The number of layers generally appears to increase with the width of the compact wall. [35]

248 At least in fish, the cardiomyocytes of the distinct compact layers may be at almost right  
249 angles to each other.[10, 36, 37] and the different myocardial layers may be so distinct that  
250 they are easily separated[35, 38, 39] In fishes, nonetheless, we have never observed findings  
251 to support the concept of a myocardial band that connects the atrioventricular orifice with  
252 the conoventricular, or bulboventricular, orifice. Reptiles, which may be considered to  
253 represent the ancestral state of mammals and birds, have a variable number of compact  
254 layers, like in fishes, but generally there are 2 or 3 layers[37, 40-42] The innermost layer is  
255 the interface between the compact wall and the trabeculated, or spongy, interior wall. It is  
256 the thinnest of the compact layers when there is a sizable compact wall. [41, 42] The  
257 ventricular compact wall of many reptile species have two zones, distinguished by the  
258 orientation of the cardiomyocytes. The smooth progression of the helical angle within the  
259 depth of the ventricular walls (Figures 1,4,5), in contrast, is a feature of all mammalian  
260 species studied to date, regardless of their size, which suggests a common geometric  
261 environment for the cardiomyocyte. This is because the geometric interplay between the  
262 inner and outer surfaces of the left ventricle, with mural thickening, is an expression of the  
263 ratio of wall thickness to chamber size, and not their absolute dimensions.[13] The  
264 ventricular wall of ectothermic vertebrates may have substantial deviations from the  
265 architectural arrangement of two distinct layers. Many species, however, do have a bi-  
266 layered compact wall, but the two layers appear largely distinct, not unlike a Russian  
267 Matryoshka nesting doll (Figure 7). Unwinding such layers would produce an outer and an  
268 inner shell, not a single band. It follows that the “aberrant fibers” that are initially disrupted  
269 in the unwinding of Torrent-Guas, are in fact an evolutionarily old part of the ventricle  
270 (Figure 7). We propose the “aberrant fibers” is a spurious concept and the disruption of  
271 such commonly found circumferential compact myocardium immediately invalidates the  
272 significance of unwinding of the heart.

### 273 **Congenital heart disease perspective**

274 There are multiple congenital lesions that point to the lack of credibility of a concept  
275 depending on the presence of a unique myocardial band extending from the pulmonary to  
276 the aortic roots, and encircling both ventricular cavities. In the first instance, it is difficult to  
277 envisage how such a concept would be compatible with the development of a heart having

278 double inlet to, and double outlet from, the right ventricle. In this setting, the left ventricle  
279 is no more than a hypoplastic apical component. It is equally difficult to envisage how the  
280 notion of a band extending from the pulmonary to the aortic roots would be compatible  
281 with the presence of a common arterial trunk. It is similarly difficult to explain hearts having  
282 either aortic or pulmonary atresia, not to mention the fact that, in Ebstein's malformation,  
283 the location of the alleged passage of the myocardial band from the right to the left  
284 ventricle inferiorly can be paper-thin due to atrialisation of the inlet component of the right  
285 ventricle. The presence of a myocardial band should have important implications for the  
286 development of congenital heart disease. We are unable to find any such evidence.  
287 Dissections performed in congenitally malformed hearts also confirm the presence of the  
288 cardiomyocytes aligned in circumferential fashion, a feature denied by some of the  
289 proponents of the band.[43] The circumferential cardiomyocytes, furthermore, were  
290 present in the hypertrophied walls of the right ventricle in a heart obtained from a patient  
291 with tetralogy of Fallot ([Figure 8](#)).

## 292 **Current understanding of myocardial structure**

293 The wealth of data available from the techniques and approaches discussed above shows  
294 that the myocardial walls are made up of cardiomyocytes aggregated together to produce a  
295 three-dimensional meshwork of interconnected units. The average orientation of  
296 cardiomyocytes show a gradual change in their helical angulation, with a middle component  
297 having approximately zero angulation relative to the ventricular equator. There are no gaps  
298 in the assembly of the units that would permit a dissector to begin to reveal the presence of  
299 a unique myocardial band. Nor are there planes of cleavage that would permit the tracing of  
300 such a band from the pulmonary trunk to the aortic root, particularly when note is taken  
301 that the outer wall of the left ventricle is held, by proponents of the band, to contribute to  
302 both its basal and apical loops. Lev and Simpkins had already emphasized, in 1965, that  
303 under the conditions employed by Torrent-Guasp, the ventricular muscle mass can be  
304 dissected almost at the whim of the anatomist.[44] We do not deny that, with skill and  
305 practise, it is possible to unravel the heart to produce a continuous myocardial band.  
306 Indeed, it is now possible to observe Torrent-Guasp producing the strip on an online  
307 video.[2] The important question is whether Torrent-Guasp is producing the band according

308 to his own pre-conceived notions, or on the basis of the accepted techniques for anatomic  
309 dissection. When analysing the arrangement of adjacent skeletal muscles, relatively uniform  
310 dissections are produced simply by delimiting the boundaries of the individual muscles, with  
311 the skeletal myocytes aggregated together within epimysial sheets. Such an approach is not  
312 possible when considering the ventricular cone, since the cardiomyocytes within the  
313 ventricular walls are aggregated together by the endomysial components of the fibrous  
314 matrix, and by their own branched connections via the intercalated discs. The aggregated  
315 units themselves are separated by perimysial spaces, with the overall walls enclosed  
316 between the epicardial and endocardial boundaries. There are no obvious planes of  
317 cleavage that permit delimitation of anatomically defined tracts or subunits within the walls.  
318 Observation of the approach taken by Torrent-Guasp reveals that his initial separation of  
319 the right ventricle tears away its parietal wall from the ventricular septum, disrupting what  
320 are described as “aberrant fibres” ([Figure 3](#)).[2] They are, of course, only aberrant according  
321 to the preconception of the band. In reality, these cardiomyocytes can be shown, by  
322 following the grain produced by the aggregated chains, to form a myocardial component  
323 common to both ventricles.[12, 14] Having reached the inferior interventricular groove,  
324 Torrent-Guasp then alleges to show loops of the band that encircle the left ventricle. The  
325 plane developed by Torrent-Guasp is within the aggregated cardiomyocytes that surround  
326 the cavity of the left ventricle in circumferential fashion. Such circular cardiomyocytes,  
327 denied by current proponents of the band, are well demonstrated by dissections made  
328 following the overall alignment of the aggregated units (Figure 1). Detailed anatomical  
329 analysis, therefore, using all available techniques, contradicts the hypothesis of the band.

### 330 **Conclusions**

331 There is extensive experimental evidence to show that the ventricular walls are made up of  
332 an intricate three-dimensional network of aggregated cardiomyocytes. Apart from the  
333 questionable blunt dissections performed by Torrent-Guasp, there are no direct or indirect  
334 observational data to support the concept of a compartmentalised ventricular myocardial  
335 band that extends from the pulmonary trunk to the aorta (see on-line supplement- Table).  
336 We submit that the notion of a unique myocardial band is anatomically spurious. Taken with  
337 our second review,[45] we conclude that the value of the band as an explanation of

338 ventricular structure, function and cardiac pathophysiology has come to an end.

339

340 **Figures:**

341 **Figure 1. Macroscopic anatomy of the porcine heart**

342 Blunt dissection of the heart shows the gradual transition of the helical angle of the inner,  
343 midwall and outer zones (black lines) compared with the long axis (red line). Figure kindly  
344 provided by Prof PP Lunkenheimer.

345 **Figure 2. Macroscopic anatomy of the human heart**

346 As seen in Panel A, the dissection of a human heart reveals that the cardiomyocytes of the  
347 superficial layer are common for both ventricles, descending obliquely on the sternocostal  
348 and diaphragmatic aspects to the apex, crossing the interventricular grooves. The course of  
349 the cardiomyocytes around the right ventricle is more circumferential than in the left  
350 ventricle. Panel B shows that the grain of the middle layers of both the right and left  
351 ventricle are orientated in a second direction.

352 **Figure 3. Microscopic anatomy of the human heart**

353 Cross-section of human heart at the equator stained using Masson's trichrome technique.  
354 The dashed arrow indicates the region where the dissection as performed by Torrent-Guasp  
355 damages cardiomyocytes whilst entering the right ventricle. The solid arrow shows the  
356 disruption required within the mid-zone of the circumferentially orientated cells. The  
357 presence of aggregated units is evident, forming chevron-like structures around most of the  
358 ventricular circumference.

359 **Figure 4. Eigen analysis of the human heart using microcomputed tomography**

360 Angle maps are viewed in short axis and colour bars indicate cardiomyocyte helical  
361 angulation. Note the cardiomyocytes with a helical angle close to zero (blue) encircling the  
362 entire circumference of the mid-ventricular wall.

363 **Figure 5. Transmural tangential reconstructions using high resolution microcomputed**  
364 **tomography**

365 Figure 5 shows cardiomyocyte aggregates in the subepicardial (1), outer (2-4), midwall (5-7),  
366 inner (8-9) and sub endocardial zones (10) from a rabbit heart. Similar transitions are seen  
367 around full circumference of the left ventricle. Note a gradual transition in angulation that is  
368 not compatible with a concept of the “unique myocardial band”. Spatial resolution  $\sim 6\mu\text{m}$ .

369 **Figure 6. Embryological findings**

370 Figure 6A shows a hematoxylin-eosin staining cross-section in a human fetus of 20 weeks of  
371 development. Note the changing orientation from radial lamellae to circular orientation,  
372 with formation of chevrons. There is no evidence of the “edges” that would be required to  
373 support the notion that the walls are made up of a wrapped band, nor evidence of fibrous  
374 partitions separating the components of the alleged band. A short axis map of the helical  
375 orientation of the cardiomyocytes using DTMRI in a human heart at 24 weeks of gestation is  
376 shown (6B). Colour coding indicates helical angle, such that blue indicates circumferentially  
377 orientated cardiomyocytes.

378 **Figure 7. Comparative anatomy.**

379 Ventricular architecture in a frog and a snake illustrated by  $10\mu\text{m}$  thick transverse sections  
380 stained with picro-sirius red. The (contracted) ventricle of the *Xenopus* frog exemplifies the  
381 highly trabeculated found in many fishes and amphibians. The arrows show three pathways  
382 where no myocardium was crossed and by which the extremely thin outer compact layer can  
383 be reached from the central lumen. Distinct layers to the compact wall is not recognized in  
384 such settings, and even if they were, the functional implications would be proportional the  
385 mass of the layers, that is miniscule. The ventricle of pythons has a high-pressure left



386 ventricle (LV) and a low-pressure right ventricle (RV) surrounded by two distinct layers of  
387 compact myocardium (This ventricle was fixed in diastole). Where the dashed arrow is  
388 placed (as in Figure 2), much of the compact wall is made up of approximately  
389 circumferential oriented myocardium. The presence of this myocardium suggests an old  
390 evolutionary origin to the so-called “aberrant fibers” that has to be disrupted initially in the  
391 Torrent-Guasp procedure. We propose “aberrant fibers” is a spurious concept and further  
392 propose the disruption of such commonly found circumferential compact myocardium  
393 immediately invalidates the significance of unwinding of the heart.

#### 394 **Figure 8. Ventricular architecture in tetralogy of Fallot.**

395 The dissection reveals the macroscopic features in the setting of tetralogy of Fallot, showing  
396 a middle layer with a circumferential orientation in the right ventricle (arrow). The presence  
397 of circumferential cardiomyocytes in a direction perpendicular to the direction of the ‘basal  
398 loop’ is incompatible with the concept of a “unique myocardial band”.

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