Three-Dimensional Architecture of Cardiomyocytes and Connective Tissue in Human Heart Revealed by Scanning Electron Microscopy

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Scanning electron microscopy is a useful modality to directly observe the 3-dimensional structures of cells at high resolution. Scanning electron microscopy enables visualization of the surface features of cardiomyocytes after removal of the surrounding connective tissue[1] and the connective tissue skeleton after removal of the nonfibrous elements.[2] In addition, backscattered electron emission with heavy metal staining[3] helps to provide high-quality images of the intracellular architecture of the cardiomyocyte.

In this study, we present the 3-dimensional structure of the human left ventricular myocardium from subjects without apparent cardiac abnormalities at the time of autopsy. Backscattered electron emission provides a high-contrast picture of the subsarcolemmal sarcomeres and intercalated discs as seen in longitudinally arranged cardiomyocytes (Figure 1A). The cardiomyocytes are seen to be branched and connected with the adjacent cells via intercalated discs. At higher magnification, in the sarcomeres, the A bands can be identified as broad bright zones, the I bands are seen as dark zones, and the Z bands are demonstrated as indistinct thin lines in the middle of I bands (Figure 1B).

After the removal of the nonfibrous elements, interstitial connective tissue surrounding the cardiomyocytes and small vessels can be clearly observed (Figure 2A). The perimysium, located around the bundle of cardiomyocytes, and the endomysium tether surrounding the individual cardiomyocytes are clearly demonstrated[4] (Figure 2B and 2C). At high magnification, collagen fibers are identified as forming a complex network and providing the strength sufficient to support the 3-dimensional structure comprising cardiac muscle fibers and neighboring vascular tissues (Figure 2D).

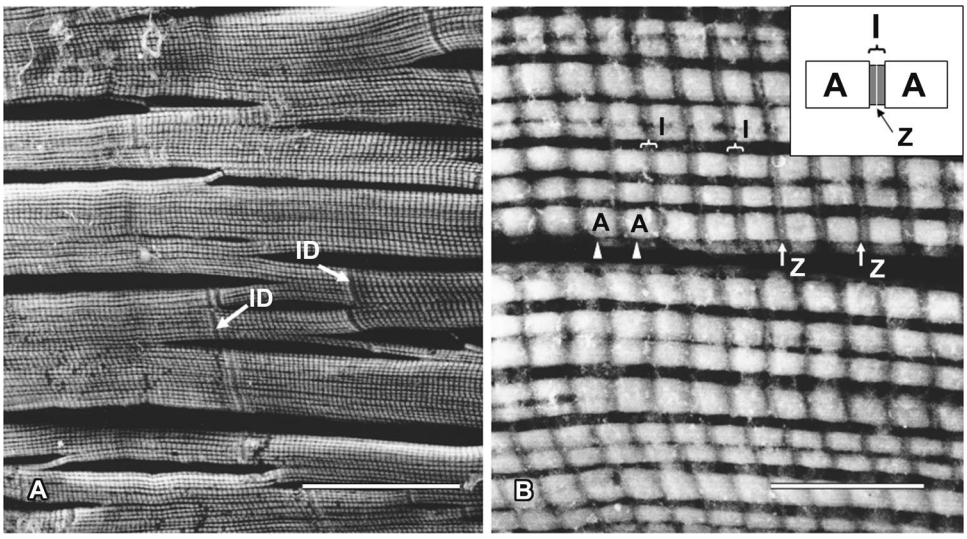

Figure 1. Backscattered electron imaging of normal human left ventricular cardiomyocytes. A, Intercalated discs (arrows) and sarcomere striations are clearly seen. Bar=50 μm; magnification ×600. B, Higher magnification of the sarcomeres; A bands (arrowheads) are seen as broad bright zones, I bands as dark zones, and Z band (arrows) as indistinct thin lines in the middle of the I bands. The schema is presented in the boxed area. Bar=10 μm; magnification ×3000. ID indicates intercalated disc; A, A band; I, I band; and Z, Z band.

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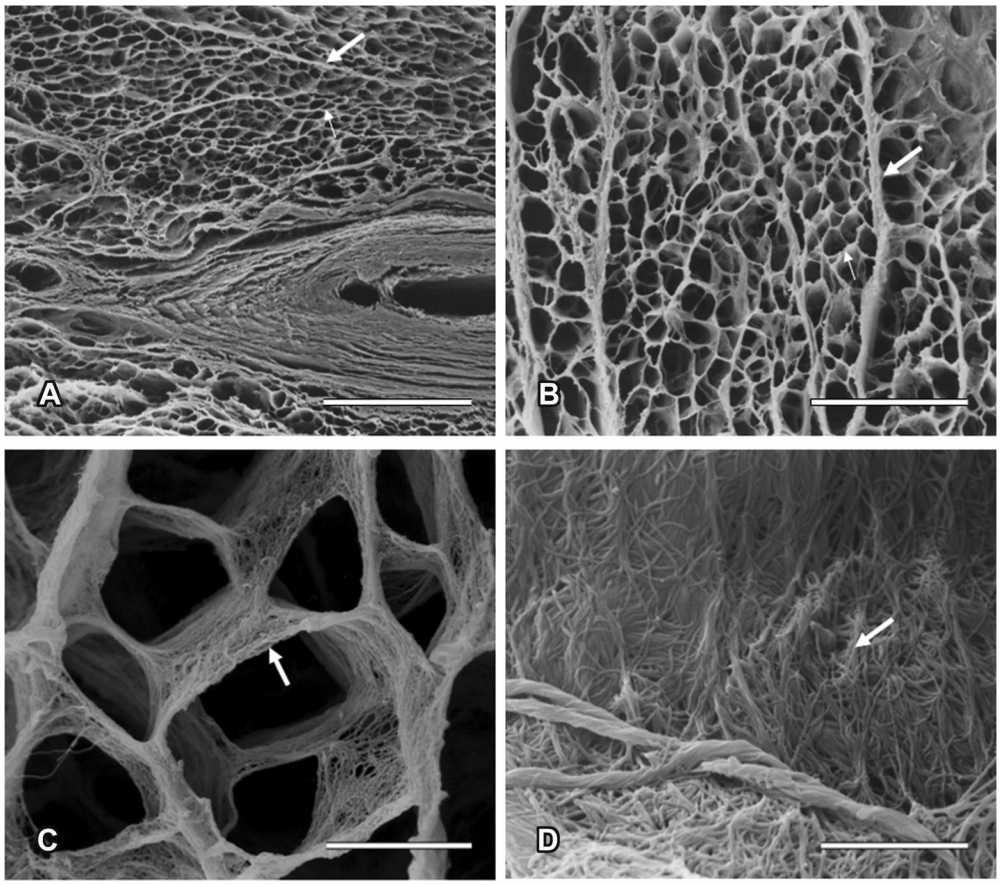

Figure 2. Connective tissue skeleton of human heart (transverse section). A, The collagen network around cardiomyocytes and small vessels is clearly observed. Bar=200 μm; magnification ×150 (thick arrow, perimysium; thin arrow, endomysium). B, The interstitial connective tissue consisting of perimysial and endomysial components presents a honeycomb shape. The perimysium (thick arrow) surrounds groups of cardiomyocytes, and the endomysium (thin arrow) surrounds each cardiomyocyte. Bar=100 μm; magnification ×300. C, The endomysium supports and connects individual cardiomyocyte fascicles. Bar=10 μm; magnification ×3000. D, At higher magnification, collagen fibers show interconnections on the surface of cardiomyocytes. Thin collagen strands are probably collagen III (arrow). Bar=3 μm; magnification ×10 000.

Disclosures

None.

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