The Surface Morphology of the Infundibular Muscle in Patients with Tetralogy of Fallot

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Summary

The surface morphology of the infundibular muscles obtained from open heart surgery was investigated in 10 patients with tetralogy of Fallot. Various degrees of abnormal surface morphological changes were observed from the endocardium to the myocardium. In the endocardium striking proliferation of the endothelial cells was usually accompanied by focal loss of the endothelium with fibrotic change. Based on the characteristic alterations of the surface morphology 4 different groups of myocardial cells could be identified: normal myocytes, defective myocytes, sclerotic myocytes, and necrotic myocytes. Because intact surface morphology is responsible for integrated cellular function these pathological findings observed on the surface morphology of the endocardium and myocardium can provide a valuable reference to further understanding of functional disorders of the infundibular muscle in patients with tetralogy of Fallot.

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Since the scanning electron microscopy (SEM) was applied in both biology and medicine there has been an intensive focus of advanced research on cardiac muscle in recent years.1)-5) Although the ultrastructural features of crista supraventricularis muscle observed with transmission electron microscopy (TEM) have previously been described in detail in patients with various forms of congenital heart disease,6)-8) the surface morphology of the infundibular muscle has yet to be clearly defined in patients with tetralogy of Fallot.9)

The purpose of the present report is to describe the morphology and surface topography of the infundibular muscle obtained from the patients with tetralogy of Fallot, with particular emphasis on the surface morphology for further understanding of functional disorders of the infundibular muscle.
of myocardial cells.

**Materials and Methods**

Ten patients with tetralogy of Fallot were the subjects of this study. Their ages ranged from 2 to 45 years. The infundibular muscles obtained at the time of open heart surgery were immediately fixed with iced 3% glutaraldehyde in 0.1 M phosphate buffer (PH 7.2-7.4) for 2 hours. Subsequently the muscle specimens were rinsed with cold 0.1 M phosphate buffer several times, and postfixed with 2% phosphate buffer osmium tetroxide (PH 7.2-7.4) for an additional 2 hours. The tissues were then dehydrated in graded concentrations of chilled ethanol, and subjected to critical point drying. After critical point drying, samples were placed in liquid nitrogen, fractured with a pre-cooled razor blade, mounted on specimen stubs for SEM, and coated with gold. Then the specimens were examined with a Hitachi H-5010 SEM operated at 25 KV.

**Results**

In using SEM the entire surface morphology of the infundibular muscle from the endocardium to the myocardium were clearly identified. Therefore, the characteristic changes of the surface structures even at the subcel-
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Fig. 2. Simultaneous demonstration of endocardial fibrosis (short arrows) and endothelial proliferation (long arrows).
×1,600. Horizontal bar = 10 μ.

The surface morphology of the endocardium

In general, there were apparent morphological changes on the endocardial surface of the infundibular muscle. Focal areas of striking proliferation of the endothelial cells usually associated with marked variations in cell size and disorganization in cellular alignment were a common finding (Fig. 1). Areas of focal loss of the endothelium associated with fibrotic change were frequently seen (Fig. 2); however, on occasion extensive loss of the endothelium was also present. In areas of denuded endothelium the subendothelial surface had a coarsely granular appearance and was covered by fibrillar structures. Thrombi were rarely noted on the endocardial surface.

The surface morphology of myocardial cells

There were 4 different groups of infundibular muscle cells which could be identified based on the observation of the surface morphology.

Normal myocytes: These cells were morphologically normal in appearance. They generally exhibited an intact sarcolemmal surface usually with some wrinkling and finely granular appearance (Fig. 3). However, regular transverse ridges and longitudinal folds extending the length of
FIG. 3. Typical example of the normal myocytes. The sarcolemmal surface showing some wrinkling is morphologically normal. \( \times 8,000 \). Horizontal bar = 5 \( \mu \).

The cells were consistently present on the cell surface of the contracted myocytes. The surface structures at the subcellular level, such as transverse-tubular openings, could be clearly identified. The intercellular borders were also readily delineated. The collagen fibrils and/or fibers were infrequently observed on the sarcolemmal surface.

Defective myocytes: An interesting finding observed on the sarcolemmal surface of these cells was that there were various degrees of surface defects which were irregular in shape (Fig. 4). An increased amount of fibrous tissue was often seen on the cell surface. In addition to these abnormal findings the subcellular surface morphology was still preserved with well-defined intercellular boundaries.

Sclerotic myocytes: All of the muscle cells appeared rigid and small in comparison with normal myocytes. The cell surface was irregularly uneven, and was usually, but not invariably, covered by numerous collagen tissues (Fig. 5). The subcellular surface structures were not readily appreciated, and the intercellular borders were unable to be clearly defined.

Necrotic myocytes: The muscle cells were nearly or entirely destroyed,
and the individual cells could not be readily delineated with complete loss of the surface structures (Fig. 6). A great number of collagen fibers were randomly distributed on the cell surface.

**DISCUSSION**

The ultrastructural characteristics of crista supraventricularis muscle have previously been described in patients with various forms of congenital heart disease.\(^6\)-\(^8\) However, no detailed study has yet depicted the surface morphology of the infundibular muscle in patients with tetralogy of Fallot.\(^9\) In the present investigation, with SEM, we observed the surface morphological features of the infundibular muscles which were not reported in patients with tetralogy of Fallot.

The characteristic changes of the endocardium included focal proliferation of the endothelial cells and various degrees of endothelial denudation which were finally replaced by fibrous tissue. These pathological findings, rarely demonstrated in previous ultrastructural studies, indicated degenerative changes of the endocardium accompanied by regeneration of the endothelial cells. The mechanisms responsible for these pathological processes were suggested to be related at least in part to myocardial hypertrophy with marked
FIG. 5. The sclerotic myocytes showing generalized sclerotic change. A. Simultaneous demonstration of the normal (short arrows) and sclerotic cells (long arrows). The sclerotic cells show a rigid appearance with irregularly uneven surface. B. The sclerotic cells are covered by collagen fibers (arrow). The intercellular borders can not be clearly delineated. ×8,500. Horizontal bar = 5 μ. 
Fig. 6 A and B. The necrotic myocytes showing nearly complete destruction of the cells with extensive fibrosis on the cell surface. ×7,000. Horizontal bar = 10 μ.

metabolic disturbance due to chronic hypoxemia and/or ischemia.\textsuperscript{10,11}

Four distinct groups of the infundibular muscle cells could be identified based on the characteristic findings of the surface morphology. The surface morphology of the normal myocytes was intact. Although the defective
myocytes showed various degrees of surface defects which might cause functional impairment of the cells, these cells usually appeared morphologically viable. The irregularly-shaped defects on the sarcolemmal surface were considered to result from either primary pathological changes of the surface structures or the extension of the internal structural changes to the cell surface. The abnormal morphological alterations observed on the sclerotic and necrotic myocytes varied from generalized sclerotic change to total destruction of the entire muscle cells. These pathological findings denoted advanced stages of degeneration and necrosis of the cells which occurred in the infundibular muscles of the patients with tetralogy of Fallot.6)–12) These 2 types of damaged cells were considered to be morphologically not viable.

In summary, various degrees of abnormal surface morphological changes of the infundibular muscles were consistently present in patients with tetralogy of Fallot. Because intact surface morphology is responsible for integrated cellular function we hope these pathological findings observed on the surface morphology of the endocardium and myocardium can provide a valuable reference to further understanding of functional disorders of the infundibular muscle in patients with tetralogy of Fallot.

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**References**


