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ORIGINAL ARTICLE

Morphological remarks regarding the structure of conduction system in the right ventricle

Adam Kosiński[1], Marek Grzybiak[1], Janusz Nowiński[1], Krzysztof Kędziora[2], Włodzimierz Kuta[1], Alicja Dąbrowska-Kugacka[3], Ewa Lewicka[3], Grzegorz Raczak[3], Dariusz Kozłowski[3]

[1]Department of Clinical Anatomy, Medical University of Gdansk, Poland
[2]Pneumonology Department, Medical University of Gdansk, Poland
[3]Department of Cardiology and Electrotherapy, Medical University of Gdansk, Poland

Abstract

Background: The knowledge of conduction system morphology has a vital significance in cardiology and cardiac surgery — it enables to interpret pathologies and choose treatment. This has been confirmed by numerous accounts, both in the context of e.g. atrial fibrillation ablations as well as treating septum defects. Due to diversity and changeability of conduction system structure and their clinical implications, its thorough analyses seem to bear special importance.

Aim: To examine the structure of selected elements of conduction system present in the right ventricle (RV).

Methods: Elements of conduction system present in RV of 6 foetuses (from 12 to 32 weeks of foetus age), 6 children (from 1 day to 7-year-old) and 10 adults (from 37 to 79-year-old) were histologically examined. Cross sections of 10 moderator bands and 10 anterior papillary muscles of adult human hearts were made. Specimens including membranous and muscular parts of the septum along with diverging moderator band were taken from a group of foetus, child and adult hearts. Cuttings of 10 micron width were stained with Masson's method in Goldner's modification. On the basis of the sections of membranous and muscular parts of the septum, the continuities of the elements of the conduction system were analysed.

Results: It was observed that in most cases the right branch of His' bundle locates itself deep in the muscular tissue of the septum irrespective of age; it is clearly separate along its whole run and gradually penetrates the muscular tissue with its fibers. Hardly ever does the right branch of His' bundle locate itself on the surface, subendocardially, with a minimum penetration into the muscular tissue. Moreover, in most cases, elements of conduction system are present in moderator band. The main tissue constituting its stroma is above all muscular tissue and to a lesser extent, connective tissue. In addition to this, fat tissue in variable proportion was also observed. In cross sections of the moderator band a distinctively circumscribed stripe of fibers of the conduction system was found. However, one could also observe samples in which its identification was not possible.

Conclusions: The right branch of His' bundle within the muscular part of the septum in most cases is located intramuscularly irrespective of age. The results of analyses prove a relatively constant character of the presence of the conduction system within the moderator band.

Key words: right ventricle, conduction system, moderator band

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INTRODUCTION

Knowledge of the detailed structure of the heart is a prerequisite of full understanding of its function and related pathologies. Despite many years of research conducted with an array of morphometric procedures, many controversies remain. The architecture of the right ventricular (RV) conduction system and its location (with respect to the moderator band in particular) still seem unclear. The precise knowledge of the conduction system location is particularly important in both interventional cardiology and cardiac surgery, as it facilitates effective completion of the procedure and minimises the potential risk of thromboembolic events [1]. It has been confirmed by numerous studies, both with regard to ablation procedures and septal defect closures [2].

Address for correspondence:
prof. Dariusz Kozłowski, Department of Cardiology and Electrotherapy, Medical University of Gdansk, ul. Dębinki 7, 80–211 Gdańsk, Poland, tel: +48 58 349 39 10, e-mail: dkozl@gumed.edu.pl
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Our observations represent a fragment of a wider project of RV structure analysis (including moderator band, supraventricular crest, and papillary muscles) [3, 4]. The significant discrepancy of the literature data in both defining the discussed structures and grading their clinical implications, seems to fully justify detailed studies.

METHODS

The work was performed on the material of human hearts of both genders: foetuses (6 hearts, from 12 to 32 weeks of foetus age), children (6 hearts, from 1 day to 7-year-old) and 10 adults (from 37 to 79-year-old), fixed in a formalin+ethanol solution. Only those organs were examined in which neither pathological changes nor developmental anomalies were macroscopically found. Histological examinations were carried out on transverse cross-sections of 10 moderator bands and 10 anterior papillary muscles of adult human hearts. Specimens including membranous and muscular parts of the septum together with the moderator band were taken from a group of foetus, child and adult hearts to make preparations cut in the frontal plane of the septum. Sections of 10 microns were stained with Masson's method in with Goldner's modification. The course of the elements of the conduction system was analysed, mainly the right bundle branch of His bundle (RBB). On the cross-sections of the moderator band its histological structure was investigated, not only to assess contents of particular tissues but also to observe the course of the blood vessels and, possibly, the elements of the conduction system. Photographic documentation was made of selected histological specimens, using a stereoscopic microscope with Leica MZ8/MPS60 photographic adapter. Due to the small sample size, statistical analysis was not performed.

RESULTS

It was observed that in most cases the right branch of the His bundle, initially running in the subendocardium and neighbouring with the base of the septal cusp, gradually penetrates the ventricular septal myocardium with its fibres. It was clearly visible in 4 of 10 adults, 5 of 6 children and 5 of 6 foetuses. Afterwards, RBB penetrates deep into the myocardial tissue of the septum (Fig. 1), running clearly separated inside, bending near the septal papillary muscle to finally reappear subendocardially in the moderator band's structure and continue toward the basis of anterior papillary muscle (Fig. 2). In 3 cases, however, (1 foetus heart, 1 child' heart and 1 adult heart), RBB run superficially, subendocardially, along its entire course, only slightly penetrating the ventricular septal myocardium (Fig. 3). In 2 other cases (1 foetus, 1 child), the RBB, immediately after separating of the His bundle, penetrates the ventricular septal muscular tissue deeply and directly and heads down to the base of the moderator band. The structure, irrespective of the level of transverse cross-section, presented similar histological images. The main tissue constituting its framework was primarily muscular tissue and, to a lesser extent, connective tissue. Additionally, variable amount of fatty tissue was also identified. The outside surface of the moderator band was covered with endocardium, whose elements penetrated the muscular tissue in the form of single streaks. In most instances, staining with Masson's method in Goldner's modification enabled us to discriminate between the elements of the conduction system and the muscular tissue. In transverse cross-sections of moderator band, a clearly separated streak of conduction system fibres was found in the majority of cases; there were also specimens, in which its identification was not possible (in 4 of 10 cases). Very well developed network of vessels was also observed [3].

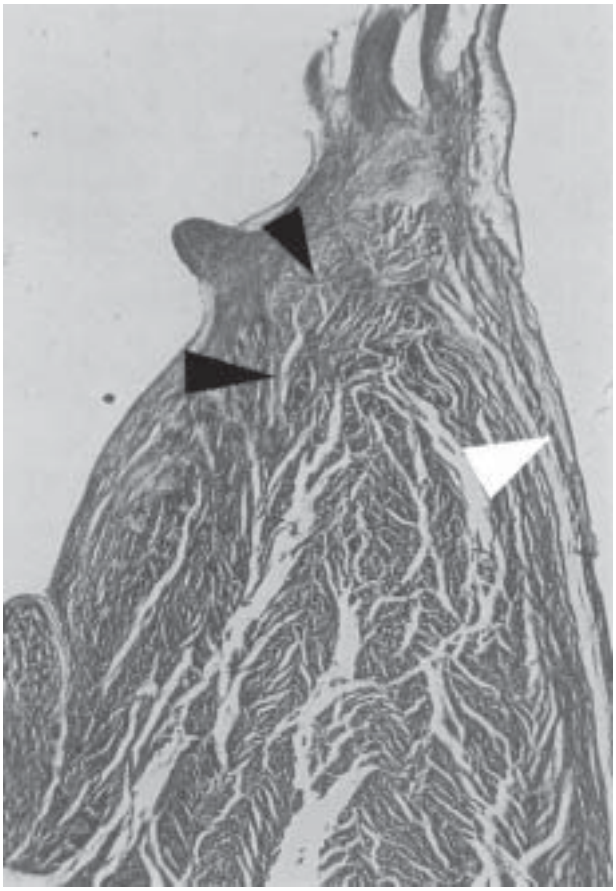

Figure 1. Ventricular septum, frontal cross-section. Black arrowheads — the right bundle branch of the His bundle, white arrowhead — the left bundle branch of His bundle, ♀, 5 days

DISCUSSION

Very few authors described the histological structure of the RV trabeculae, including the septo-marginal trabecula. Its first cross-sections are come from the work of Holmes [5] who named it a supra-ventricular trabecula. The author found unequivocal dominance of muscular tissue in the area of moderator band and the presence of conduction system elements separated by

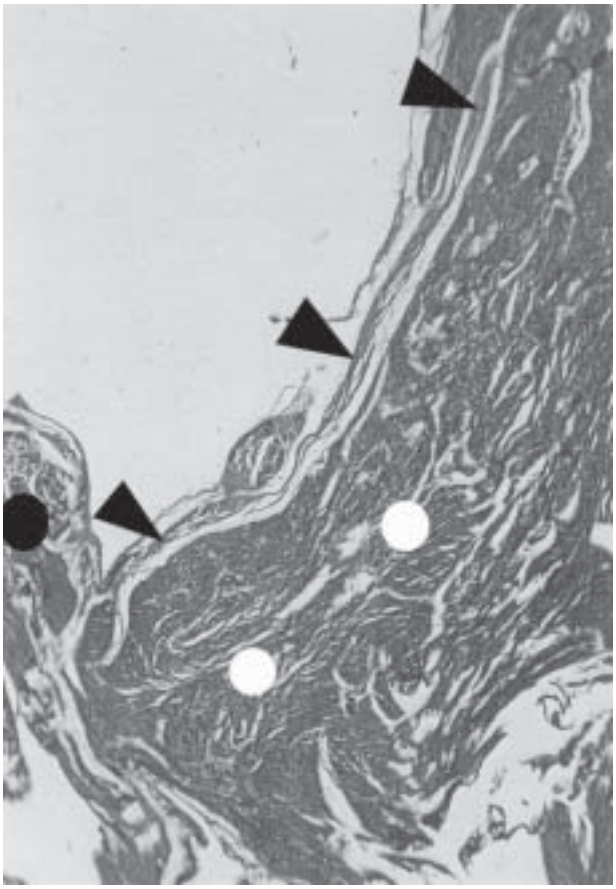

Figure 2. Moderator band (white dots) and anterior papillary muscle (black dot), frontal cross-section. Black arrowheads — the right bundle branch of His' bundle, ♂, 35 days

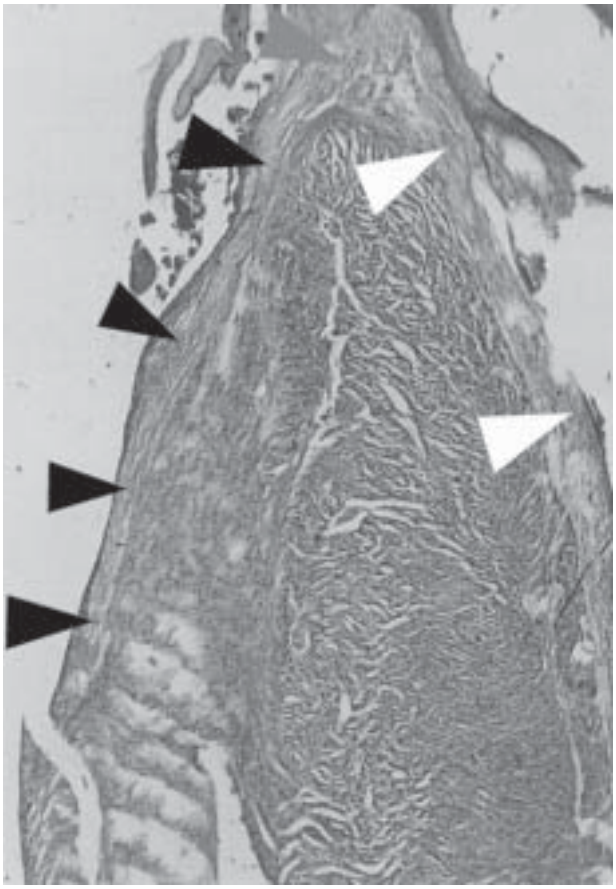

Figure 3. Ventricular septum, frontal cross-section. Black arrowheads — the right bundle branch of the His bundle, white arrowheads — the left bundle branch of the His bundle, grey arrowhead — His bundle, ♂, 1 day

a bright streak of connective tissue. These results confirm the observations from our work. However, a bigger amount of connective tissue with associated fatty tissue occur in the His bundle structure and the site of its bifurcation into left bundle branch (LBB) and RBB. Sandusky and White [6] believes that the fibres of conduction system make bundles (from 6 to 10) which are divided into sections by connective tissue. Similar findings were reported by Challiace and Viragh [7], who examined microscopic conformation of mamals' hearts as well as by Massing and James [8] in their work on age-related changes in the conduction system. Sometimes, it is difficult to identify the conduction system in the cross-sections. Truex and Copenhaver [9] didn't find it in 14 of 20 examined moderator bands. In our work, we couldn't identify those structures in 4 of 10 the examined hearts. Nevertheless, our own research and data from literature confirm the relatively constant nature of conduction system's presence in the moderator band.

Our histological specimens enabled the precise tracing of RBB course up to the level of penetration of the moderator band. According to Smith et al. [10] as well as Massing and James [8] the LBB is usually but not universally a wide structure (its width varies from 2 to 14 mm), in contrast to the narrow RBB. In some publications, the course of the RBB, just after separating of the His bundle, was described [11–14]. Davies et al. [11] emphasize very clearly that in the course of the RBB, along its entire length there are delicate, slim streaks of conduction system fibres separating from it and heading towards the ventricular septum. Our research confirmed these observations. Moreover, Davies et al. [11] underline extensive variability of the RBB in adult human hearts, citing Hudson who described the cases of RBB ending up high in the ventricular septum in the form of small strands. In our study we didn't notice such a variant.

Okabe et al. [15] performed post mortem histological examinations of 20 patients that underwent acute anteroseptal myocardial infarction. They were interested in the distance between the site of RBB necrosis and the base of the moderator band. It turned out that in 10 patients who developed a RBB block diagnosed on ECG, the necrotic tissue included its proximal segment within the distance exceeding 8 mm from the band's origin. In the second group of patients (without the

RBB block diagnosed on ECG) in 3 cases the necrosis affected the distal segment of the RBB at a distance less than 3 mm from the band's base and in 7 cases it could not be found at all. This may be a proof that damage of proximal RBB segment with some of its fibres taking off towards the ventricular septum, causes complications more often than its damage in direct proximity or in the area of the moderator band.

In our research the RBB, along its course within the ventricular septum, was always separated from other tissues by a streak of connective tissue. It should be emphasised that also in the area of the band, similar image was found and that conduction system fibres, surrounded by connective tissue, headed for the anterior papillary muscle's base. The amount of connective and fatty tissue was generally bigger in the area of His bundle and in the proximal segments of both its bundle branches; the amount increased with age — what was confirmed by the work of Erickson and Ler [16] as well as Davies et al. [11]. I should be emphasised that not only in the moderator band's transverse cross-sections but also in some of the septum's frontal cross-sections, the conduction system fibres are very similar to the working myocardial fibres of the heart.

There are many reports concerning congenital heart disease with regard to its consequences, undoubtedly including RBB course disorders. Our work demonstrated that relative location of this part of conduction system in the area of ventricular septum, may be independent of age. Kurosawa and Becker [17] emphasise that publications regarding classifications of septal defects ought to be considered in the aspect of anatomy and topography of the moderator band. Bharati and Lev [18] as well as Moene et al. [19] report that a non-branching bundle is in such cases longer. They believe that detailed classification of septal defects together with the knowledge of the most probable course of conduction system fibres in each case is of great importance for every surgeon. It enables the surgeon to do the procedure with maximum sparing of those structures and thus prevent potential complications. Serraf et al. [2] discussing surgical treatment of septal defects, mention that from technical point of view, the defects most difficult to correct are those located in its so-called trabecular part and that they frequently are multiple. Of all defects of that segment, particularly its middle-trabecular part poses the greatest challenge for operators. To reach the defect they need to cut through the moderator band area which causes the RBB block and sometimes also mild or moderate tricuspid valve insufficiency.

The knowledge of conduction system's architecture is of major importance in cardiology and cardiac surgery [18, 20, 21]. Detailed analyses of this matter allow to extend the knowledge about its diversity and changeability in the heart. It makes easier both the management and the interpretation of certain pathologies. Our own research and the presented literature data show that moderator band is a significant topographic element and good knowledge of its anatomy may result in sparing of conduction system fibres and thus preventing potential clinical complications.

CONCLUSIONS

The RBB of the His bundle in the area of ventricular septal myocardium has most frequently a deep intramuscular course, irrespective of age. Our results enable the statement of the relatively constant nature of conduction system presence in the area of moderator band.

Conflict of interest: *none declared*

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Uwagi morfologiczne dotyczące struktury układu przewodzącego w prawej komorze

Adam Kosiński[1], Marek Grzybiak[1], Janusz Nowiński[1], Krzysztof Kędziora[2], Włodzimierz Kuta[1], Alicja Dąbrowska-Kugacka[3], Ewa Lewicka[3], Grzegorz Raczak[3], Dariusz Kozłowski[3]

[1]Zakład Anatomii Klinicznej, Gdański Uniwersytet Medyczny, Gdańsk
[2]Klinika Pneumonologii, Gdański Uniwersytet Medyczny, Gdańsk
[3]Klinika Kardiologii i Elektroterapii Serca, Gdański Uniwersytet Medyczny, Gdańsk

Streszczenie

Wstęp: Znajomość morfologii układu przewodzącego ma istotne znaczenie w kardiologii i kardiochirurgii — ułatwia interpretację patologii i postępowanie terapeutyczne. Ze względu na zróżnicowanie i zmienność struktury układu przewodzącego oraz ich implikacje kliniczne, jego wnikliwe analizy wydają się szczególnie cenne.

Cel: Celem pracy było zbadanie struktury wybranych elementów układu przewodzącego zawartych w prawej komorze.

Metody: Ocenie histologicznej poddano elementy układu przewodzącego zawarte w prawej komorze 6 płodów (od 12 do 32 tygodnia życia płodowego), 6 dzieci (od 1 dnia do 7 lat) i 10 osób dorosłych (od 37 do 79 lat). Wykonano przekroje poprzeczne 10 beleczek przegrodowo-brzeżnych i 10 mięśni brodawkowatych przednich pochodzących z serc osób dorosłych. Pobrano także z grupy płodów, dzieci i serc dorosłych wycinki zawierające część błoniastą i mięśniową przegrody międzykomorowej wraz z odchodzącą od niej beleczką. Skrawki grubości 10 mikronów barwiono metodą Massona w modyfikacji Goldnera. Na podstawie przekrojów części błoniastej i mięśniowej przegrody międzykomorowej przeanalizowano ciągłości elementów układu przewodzącego, od węzła przedsionkowo-komorowego, poprzez pęczek Hisa, tzw. jego część penetrującą i rozgałęziającą się, prawą odnogę, aż do jej rozgałęzień w obrębie beleczki przegrodowo-brzeżnej. Wykonano dokumentację fotograficzną, posługując się mikroskopem stereoskopowym z przystawką fotograficzną Leica MZ8/MPS60.

Wyniki: Stwierdzono, że w większości przypadków prawa odnoga pęczka Hisa (RBB) lokalizuje się głęboko w mięśniówce przegrody międzykomorowej niezależnie od wieku; jest przy tym na całym przebiegu zwykle wyraźnie oddzielona i stopniowo oddaje włókna do mięśniówki przegrody międzykomorowej. Bardzo rzadko RBB układa się powierzchownie, podwsierdziowo, minimalnie zagłębiając się w mięśniówkę. Ponadto w większości przypadków elementy układu przewodzącego są obecne w beleczce przegrodowo-brzeżnej. Główną tkanką tworzącą jej zrąb jest przede wszystkim tkanka mięśniowa i w mniejszym stopniu tkanka łączna. Ponadto stwierdzono także występującą w zmiennej ilości tkankę tłuszczową. Zewnętrzna powierzchnia beleczki przegrodowo-brzeżnej jest pokryta wsierdziem, którego elementy wnikają jako pojedyncze pasma w głąb mięśniówki. Na przekrojach poprzecznych beleczki przegrodowo-brzeżnej najczęściej znajdowano wyraźnie odgraniczone pasmo włókien układu przewodzącego; istnieją jednak i takie preparaty, w których jego identyfikacja nie była możliwa.

Wnioski: Prawa odnoga pęczka Hisa w obrębie części mięśniowej przegrody międzykomorowej jest położona najczęściej głęboko śródmięśniowo niezależnie od wieku. Wyniki analiz pozwalają na stwierdzenie względnie stałego charakteru obecności układu przewodzącego w obrębie beleczki przegrodowo-brzeżnej.

Słowa kluczowe: prawa komora, układ przewodzący, beleczka przegrodowo-brzeżna

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Adres do korespondencji:
prof. dr hab. n. med. Dariusz Kozłowski, Klinika Kardiologii i Elektroterapii Serca, Gdański Uniwersytet Medyczny, ul. Dębinki 7, 80–211 Gdańsk, tel: +48 58 349 39 10, e-mail: dkozl@gumed.edu.pl
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