Degenerative Changes in the Human Cricoarytenoid Joint

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**Objective:** Changes in the human voice occur during the natural aging process. Occurrence of compromising alterations in the cricoarytenoid joint has been hypothesized as a possible reason for voice changes seen in advanced age and has been discussed controversially until today.

**Methods:** The present study analyzes degenerative changes in 42 cricoarytenoid joints from 21 donors (13 men and 8 women; age range, 42-98 years) by means of histological, immunohistochemical, and scanning electron microscopic methods.

**Results:** Many patients older than 40 years show distinctly altered joint surfaces at varying levels of intensity. The articular cartilage surface is fibrillated in some places. Chondrocytes near the joint surface appear as voluminous chondrocyte clusters. The superficial cartilage layer shows a positive reaction to type III and type I collagen antibodies.

**Conclusions:** Chondrocyte proliferation next to the joint surface, changed collagen synthesis, and fibrillation of the joint surface indicate degenerative alterations. Such changes are well known in cases of limb diarthroses. The changes may impair gross positional or postural movements of the arytenoid cartilages and reduce the degree and extent of vocal ligament closure. The structural changes may also lead to negative functional consequences during vocal production, such as impaired vocal quality and reduced vocal intensity due to air leakage through incompletely or loosely approximated vocal ligaments.

**RESULTS**

The 21 investigated specimens showed degenerative changes in 1 or both CAJs (Table). Results are related only to the joints with an altered joint surface.

**LIGHT MICROSCOPY**

Degenerative articular cartilage of the cricoid and arytenoid facets showed numerous fibrillations, especially in the superficial cartilage layer (Figure 1). Adjacent to the fibrillations, there were several chondrocyte clusters consisting of 4 to 10 cells (Figure 1). They revealed marked Alcian blue staining (pH, 1.0) only around the clusters. Staining appeared to be reduced or absent in the surrounding territorial and interterritorial matrices.

Chondrocytes of deeper cartilage layers showed a normal aspect. Intensive staining of these chondrocytes and their territorial matrices with Alcian blue (pH, 1.0) was found throughout the deeper car-
MATERIALS AND METHODS

Forty-two CAJs (from 13 men and 18 women; age range, 42-98 years) obtained from 21 body donors from the Department of Anatomy, Christian-Albrechts-University of Kiel, Germany, showing an altered joint surface were chosen for the study after their joint capsules were opened and their joint surfaces investigated with a magnifying glass (Table). Limited information was available on the specimens, which were taken from individuals without recent trauma or diseases that might involve or affect laryngeal function.

The Table shows the investigative method used for each CAJ. Sixteen joints (from 10 men and 6 women; age range, 42-98 years) were fixed in 4% formalin, decalciﬁed in 20% EDTA, embedded in parafﬁn, and sectioned in 3 planes. Sections (7 µm) were stained with toluidine blue O (pH, 8.3), Alcian blue (pH, 1.0), and resorcin-fuchsin-thiazin–picric acid, and by the method of Gomori according to the instructions of Romeis. Immunohistochemical investigations of extracellular matrix components were performed on cryosections of unfixed material (from 4 men and 4 women; age range, 47-78 years) that were frozen in liquid nitrogen. Polyclonal antibodies to collagen type I, type II (Biodesign, Kennebunk, Me), type III (BioScience Products AG, Emmenbrucke, Switzerland), and type IX were used. For scanning electron microscopy, 18 CAJs (from 12 men and 6 women; age range, 34-98 years) were separated into 36 articular facets. Six facets (3 cricoid and 3 arytenoid) were cut into 2 parts mediosagittally. Afterward, all facets and facet halves were ﬁxed in 2.5% glutaraldehyde for 1 week. Six facets (3 cricoid and 3 arytenoid) were investigated without preceding maceration. The method of Ohtani et al was used for detailed representations of collagen fibrils in the articular cartilage of 7 CAJs. Eight CAJs were macerated in 10% hypochloric acid at 67°C for 15 to 30 minutes and then brieﬂy rinsed in distilled water. All tissue blocks were impregnated in 2.5% tannic acid for 2 days. A counterﬁxation in 2% osmium tetroxide for 4 hours was followed by dehydration in ethanol and drying in a critical point dryer. Articular facets were coated with gold and analyzed with a scanning electron microscope (Philips GmbH, Kassel, Germany).

SCANNING ELECTRON MICROSCOPY

Scanning electron microscopy revealed alterations of the articulating arytenoid and cricoid facets at varying levels of intensity (Figure 2). The earliest stage in the development of the lesion is characterized by a roughening of the articular surface, showing a cobblestone appearance (Figure 3). After maceration of the cartilage surface in roughened areas, large chondrocyte cavities were visible next to the joint surface (Figure 4). Advanced articular cartilage degeneration appeared as fibrillation of the superficial layer and led to exposure of collagenous ﬁbers in a delimited area (Figure 5). In most cases, only 1 degeneration focus is found per articular facet (Figure 2). Such a focus may affect most of the articular facet. In 3 joints, more than 1 degenerative focus was observed per facet. Degenerative changes occur more frequently and with higher intensity in the cricoid articular cartilage than in the arytenoid cartilage.

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Our investigation with antibodies to both type I and type III collagen indicated a high immunoreactivity in some areas of the superﬁcial cartilage layers (Figure 6). These areas correspond to the areas of chondrocyte cluster formation seen in light microscopy and the areas of surface roughened seen in scanning electron microscopy. Deeper cartilage layers do not react to these antibodies (Figure 6). The deeper zones show an intensive response to antibodies to type II and type IX collagen, whereas the superﬁcial layers reveal only weak or no reactivity to these antibodies in the areas of articular surface degeneration.

COMMENT

Aging of the voice is a complex process that has been poorly understood to date. A wealth of investigations have been carried out to study changes in the voice and laryngeal morphologic features with advancing age. In this context, discussions on the structural changes of CAJs have been controversial. Segre describes the ero-
sion of joint surfaces in the larynges of elderly individuals. Kahane and coworkers\textsuperscript{7,8} find an unevenness of the cricoarytenoid articular surface with erosion, nicking, and fissurelike defects in some investigated joints. Using the India ink pinprick technique, they demonstrated that the changes are accompanied by a loss of viscoelasticity and fraying of collagenous fibers. They hypothesize that the alterations might influence the smoothness of the joint surface and, consequently, joint movement. This leads ultimately to glottal incompetence and concomitant senescent changes in the voice. By contrast, Casiano et al\textsuperscript{9} do not find articular surface irregularities in CAJs. They speculate that the fixation method used by Kahn and Kahane\textsuperscript{7} could have created artifacts in the older tissue and doubt the occurrence of detrimental alterations in CAJs of older patients.

The results of the present study show chondrocyte proliferation and changed collagen synthesis next to the
joint surface as well as fibrillation of the joint surface in CAJs of elderly individuals (Table) and thus verify the observations made by Segre. Kahn and Kahane, and Kahane and Hammons. In joints of the limbs, senile changes appear predominantly in deeper cartilage zones, whereas osteoarthritis first occurs in the superficial layer of articular cartilage. In osteoarthritis, chondrocytes undergo metabolic changes because of a lack of balance between the quantity of joint load and the load capacity of the supporting tissue involved in joint structure composition. In the early stages of the disease, there is a notable reduction of type IX collagen production. This leads to diminished cross-linking among type II collagen fibrils. The changes are distinguished by a roughening and degeneration of the articular surface, which is characterized by fibrillation of superficial cartilage.

As a result of damage in later stages of osteoarthritis, the integrity of the collagenous network is violated and its strength is lost. Cartilage becomes susceptible to mechanical rupture, the matrix splits, degeneration occurs, and vertical fissures arise in the cartilage surface. Large amounts of proteoglycans are washed out through the destroyed net of collagen fibrils into the joint cavity because of numerous fissurations and fissures. The loss of proteoglycans accounts for the reduced Alcian blue staining in the territorial matrix. The remaining aggregates of the physiologically underhydrated proteoglycans are thus able to bind to large amounts of water. Under the influence of joint load, this leads to an impaired exchange of water between the cartilage and joint cavity and, consequently, to insufficient nutrition of the articular cartilage.

Degenerative changes in the cartilage occur simultaneously with attempts to repair the matrix. Cell clusters adjacent to the joint surface are characteristic of mechanically caused arthrosis. The Alcian blue technique reveals staining only around the clusters. Different collagen types, for example, types I, III, and X, also appear in the disrupted areas, which does not usually occur in adult joint cartilage.

The degenerative alterations in CAJs of elderly individuals presented herein can be compared with morphologic osteoarthritic changes in limb joints. Osteoarthritis in CAJs is demonstrable in persons aged 40 years or older. In elderly patients, the incidence is approximately 50%; thus, osteoarthritis is not a rare event (Table). This high incidence may be due to joint biomechanics, whereas further discussion is necessary to determine whether a partial loss of articular surface contact between cricoid and arytenoid cartilage occurs during addition of the arytenoid cartilage. A comparable pathogenesis has been hypothesized for the carpadomocarpal joint of the thumb.

In conclusion, the described degenerative changes in human CAJs are comparable to osteoarthritis in limb joints and may impair gross positional and postural movements of the arytenoid cartilage. The structural changes may impact respiratory and protective functions of the larynx and thus may have negative functional consequences for vocal production. For example, impaired smoothness of arytenoid motion could reduce the extent and degree of vocal ligament approximation during phonation, leading to apecroidity in the vocal signal and thereby diminishing vocal quality. Such a voice is also likely to be reduced in intensity because of air leakage through incompletely or loosely approximated vocal ligaments.

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REFERENCES