Paraspinal Muscle Pathology in Experimental Scoliosis

C. Barrios1, M.T. Tuñón2, W. Engström3, and J. Cañadell1

1 Department of Orthopedic Surgery, Navarra University Clinic, Pamplona, Spain
2 Department of Pathology, Hospital of Navarra, Pamplona, Spain
3 Department of Pathology, Karolinska Hospital, Stockholm, Sweden

Summary. Paraspinal muscle biopsies from ten rabbits with experimentally induced scoliosis and from four healthy controls were analyzed histologically and histochemically. Scoliosis was induced by two different methods: six animals underwent unilateral damage of the dorsal column of the spinal cord (mean curve: 22°) and four costotransversectomy (mean curve: 47°). In eight scoliotic animals myopathic changes were detected on the muscles of the concave side. Only those animals which underwent costotransversectomy showed a neuropathic pattern with chronic denervation changes on the convex side. As regards the fiber type distribution, the control group showed a higher percentage of type-I fibers, which were similar on both sides of the spinal cord. No fiber proportion asymmetry could be detected in the muscles on the concave side in normal or scoliotic rabbits. There was a tendency to depart from normal values, in two different ways, on the convex side of scoliotic animals. Thus, in contrast to the medullary damage group, the muscles of the costotransversectomized rabbits showed an increased proportion of type-I fibers. Taken together, our findings support the hypothesis that myopathic changes as observed in human idiopathic scoliosis are a consequence of the postural deformity. Fiber type distribution does not appear to be related to the curvature in the same way.

Functional muscular imbalance and abnormal fiber type distribution in the paraspinal muscles have been suggested to be underlying causes of idiopathic scoliosis [3, 4, 9, 10]. Several electromyographic and histochemical studies have shown that paraspinal muscles may play a pivotal role in the progression of human scoliosis, but these reports are still controversial [5, 8, 12, 14–16].

One important issue has hitherto not been properly addressed. It is still unclear whether the reported pathological changes are a primary myogenic or neurogenic factor causing scoliosis or whether they only represent an adaptative functional mechanism induced by the postural deformity.

Although much research has been directed toward the muscles in scoliosis, few studies have dealt specifically with the influence of a progressive scoliotic curve on paraspinal muscles. Spencer and Zorab [11], working with rabbits in which scoliosis was experimentally induced using Langenskiöld’s plaster cast technique [7], found no histomorphological asymmetry in the paraspinal muscles of either normal or scoliotic animals, on both sides of the spine.

This study was aimed at investigating this issue in greater detail. More specifically, we have analyzed the paravertebral muscles of ten rabbits with experimental scoliosis induced by two different methods, namely medullary damage and costotransversectomy. The findings were compared with those from a control group of rabbits without spinal deformity. By this approach it is possible to elucidate whether there are side-related morphological changes in scoliosis and to evaluate the role of the fiber type distribution in the progression of the deformity.

Material and Methods

Scoliosis was induced experimentally in ten 4-week-old rabbits. Unilateral damage of the dorsal column and posterior horn of the spinal cord, as described by Barrios et al. [1], was the technique employed for induction of scoliosis in six rabbits. The mean angle of the curvatures was 22° (range: 8°–62°) at the end of the experiment (Fig. 1). The other four rabbits underwent costotransversectomy at three levels in the middle-low thoracic spine, as described by Langenskiöld and Michelsson [6]. More
Fig. 1a, b. Scoliotic curves induced by medullary damage. 
\textit{a} Roentgenograms of a specimen showing the severity of the scoliosis with a characteristic wedging of vertebral bodies. \textit{b} Anatomic detail of a specimen in which the rib cage was partially removed to observe the deformity with asymmetry of the intercostal spaces at the apex level.

Severe scoliosis were obtained by this method, being the mean angle $47^\circ$ (range: $39^\circ$-$69^\circ$). In all curves the apex was located between T-8 and T-10.

Animals of the control group underwent the same type of surgery as those in the experimentally induced scoliotic group. This included deinsertion of the paraspinal muscles at both sides of the thoracic spine, in order to study the influence of the surgical approach on the morphology of the paraspinal muscles.

Open biopsies of the deep paraspinal muscles were taken from each side of the scoliotic curve at the apex level when the animals were 12 weeks old. Normal spinal muscle was taken from four same-aged nonscoliotic rabbits from an area corresponding to the apex level of the curve in scoliotic animals.

Muscle samples were snap-frozen in isopentane cooled by liquid nitrogen and stored at $-70^\circ$C until processing. Transverse sections $8\mu m$ thick were cut and routinely stained with hematoxylin and eosin. Parallel samples used for histometric studies were stained with ATPase at pH 9.4, ATPase preincubated at pH 4.3, and NADH [2]. In each case, the specimens were large enough to ensure the analysis of at least 100 fibers per sample.

Fig. 2a, b. Microscopic pictures of a mid-thoracic paraspinal muscle (right side) from a nonscoliotic rabbit. \textit{a} Normal histological pattern. HE, $\times 35$. \textit{b} Type-I and type-II fiber distribution showing a high proportion of type-II fibers. NADH, $\times 17$

The muscles exhibited the normal mosaic pattern of light- and dark-stained fibers when stained for enzymatic activity (Fig. 2b). The paraspinal muscles of the mid-thoracic level showed a higher percentage of type-II than type-I fibers (approximate ratio 3:1). No significant difference was found in the mean percentage of the fibers on either side of the spine (Table 1).

\section*{Results}

\subsection*{Control Group: Nonscoliotic Animals}

The general histological appearance of the paraspinal muscles of nonscoliotic rabbits did not differ from that of those reported by Spencer and Zorab [11], which were considered normal. The muscle fibers were closely packed, polygonal in shape, and regular in size. Furthermore, the fibers were grouped together into bundles, with a thin layer of perimysium between each fascicle (Fig. 2a).

\subsection*{Scoliotic Animals}

Eight of ten scoliotic animals showed morphological changes on the concave side, as judged by microscopic examination. These included an increase in connective tissue, rounding of fibers, variability of fiber size, splitting of fibers, presence of internal nuclei, and a few atrophic fibers. These pathological findings indicate a myopathic pattern in the absence of signs of regeneration or denervation of muscle fibers (Fig. 3). The morphological changes did not appear to be related to the degree of curvature. In the other two