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Idiopathic Scoliosis

Long-Term Follow-up and Prognosis in Untreated Patients*

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ABSTRACT: **Two hundred and nineteen patients with untreated adolescent idiopathic scoliosis who were seen at the University of Iowa between 1932 and 1948 were studied, and recent information was available on 194 of the patients. The mortality rate was 15 per cent. Backache was somewhat more common in these patients than in the general population, although it was never disabling. The backache was unrelated to the presence of osteoarthritic changes on roentgenograms. Many curves continued to progress slightly in adult life, particularly thoracic curves that had reached between 50 and 80 degrees at skeletal maturity. The lumbar components of combined curves between 50 and 74 degrees also tended to progress. Pulmonary function was affected only in patients with thoracic curves.**

There have been few long-term follow-up studies of patients whose idiopathic scoliosis was not treated surgically[5,7,11,20,21]. In an attempt to delineate further the natural history of adolescent idiopathic scoliosis, we made an exhaustive search in order to re-study the patients first reported on by Ponseti and Friedman in 1950 and by Collis and Ponseti in 1969. Collis and Ponseti studied only those patients whose deformity began after the age of eight years. They were able to locate 245 of the 358 patients seen in the Department of Orthopaedic Surgery at the University of Iowa between 1932 and 1948. They excluded six patients: one with an unrecognized Friedreich's ataxia, two with curves of less than 15 degrees, and three who had spine fusions done before the age of seventeen. We attempted to contact the remaining 239 patients (through living relatives, neighbors, state driving-license bureaus, addresses, newspaper advertisements, and television programs) and were able to locate 206 (86 per cent) of the patients. In addition, we were able to find thirteen patients who had been included in the 1950 study but who could not be located for the 1969 study.

Each patient was asked to come to Iowa City for a complete evaluation. If they were unable to comply, they were asked to fill out a questionnaire and also to have a standing anteroposterior roentgenogram of the spine made and sent to us. Twenty patients declined to participate in this study and thirty-three patients had died, sixteen of them between 1968 and 1978. In addition to the three patients who had had spine fusions as adults prior to 1968, two more patients were excluded from our study for that reason.

Seventy-six patients returned to Iowa City for complete evaluation and eighty-five patients responded to the questionnaire; forty-four of the eighty-five sent along the requested roentgenogram. Therefore, we obtained current information on 161 living patients. We were able to obtain information on thirty-three deceased patients in addition. Pulmonary function studies were done on sixty-nine of the seventy-six patients who returned for examination.

The purposes of this paper are to report on the long-term follow-up of 194 patients with untreated adolescent idiopathic scoliosis, to analyze their course according to the type of existing curve, and to evaluate the long-term pulmonary effects of the untreated scoliosis.

Present Status of the Patients

The ages of the 161 living patients ranged from forty-two to seventy years, with an average of fifty-three years. Our follow-up on them ranged from thirty-one to fifty-one years, with an average of 39.3 years. One hundred and thirty-six patients (84 per cent) were women and twenty-five (16 per cent) were men. Seventeen (11 per cent) of the 161 patients never married. The 144 who married had an average of 2.8 children per family. There were only two women who had to have cesarean sections; they attributed significant complications during pregnancy or delivery to the spinal deformity.

Fifty-nine patients (37 per cent) had thoracic curves, forty-one (25 per cent) had lumbar curves, forty-two (26 per cent) had combined or double major curves, and nineteen (12 per cent) had thoracolumbar curves. At the time of writing, the measurements of the main curve in the 120 living patients with current roentgenograms were as follows: thirty-four patients (28 per cent) had curves of less than 50 degrees; thirty-eight (32 per cent) had curves of between 50 and 74 degrees; thirty (25 per cent) had curves of 75 to 99 degrees; and eighteen patients (15 per cent) had curves of more than 100 degrees. The data on the present status of the 161 patients, subdivided according to the type of curve, are listed in Table II.

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All but four of the patients were normally active. Most either were homemakers or were gainfully employed. The four exceptions (3 per cent) had these disabilities: one patient recently had a coronary bypass operation for severe atherosclerotic coronary vascular disease; one had severe obstructive pulmonary disease; one, severe congestive heart failure secondary to myocardial infarction; and one, severe rheumatoid arthritis. The occupations of the women were quite varied: homemakers, secretaries, teachers, nurses, assembly-line workers, and so on. The men's occupations similarly were varied. Because of back problems, nineteen (12 per cent) of the 161 patients somewhat restricted their occupational or recreational activities. One hundred and two patients (63 per cent) believed that their deformity was apparent to others when they were clothed, while fifty-seven patients (36 per cent) thought that their deformity was not noticeable. Two patients were unsure.

Thirty-four patients (21 per cent) had mild psychological reactions to their deformity, such as unwillingness to wear tight-fitting clothes or a bathing suit. Some patients with severe curves were not bothered, while others with minimum deformity expressed severe psychosocial limitations. None of the psychological reactions to the scoliosis were severe enough to require psychiatric treatment, and most patients said that they were more self-conscious during their teen-age and early adult years than when they were older.

Back Pain

This symptom varied in severity in this group of patients, ranging from minimum discomfort to a bothersome backache requiring occasional rest in bed. Most commonly a patient would have a mild backache at the end of a strenuous day or after unusual activity, relieved promptly by rest. For comparison, we estimated the incidence of back pain in a control group of 100 patients visiting the Dermatology Clinic. The control patients were matched for age and were screened to be certain that they did not have scoliosis (Table I). The location of the pain in the scoliotics was recorded as involving: the apex of the curve, the concavity of the curve, the interscapular region, the suprascapular region, the paraspinous muscles, or occasionally the lower ends of the ribs (when they were in contact with the iliac crest). The difference between the scoliotic and control groups was not considered important. Twelve per cent more of the scoliotics had frequent or daily pain, but 6 per cent fewer saw a doctor for the pain and only 6 per cent were hospitalized for it, compared with 16 per cent in the control group.

Fewer of the patients with thoracic curves reported back symptoms than those with other curve patterns. The severity of the curve, whatever the type, could not be correlated with back symptoms. Fifteen (25 per cent) of the fifty-nine patients with thoracic curves complained of frequent or daily backache, and eight of these patients sought the aid of a physician for their symptoms. None of them, however, had been hospitalized because of backache. A severe rib hump was observed in many, but usually the shoulders were level and trunk balance was good as determined by a plumb line. No patient had trunk decompensation of more than 3.5 centimeters. The largest rib hump measured eight centimeters. These data may be compared with those of the patients with other types of curves (Table II). Thus, with combined curves, eighteen (43 per cent) of forty-two patients had significant back pain, while with lumbar curves the number was seventeen (42 per cent) of forty-one and for thoracolumbar curves, ten (52 per cent) of nineteen. Six of the latter ten patients consulted a physician for the back pain and two of them required hospitalization.

TABLE I

INCIDENCE OF SYMPTOMS IN THE BACK

	Scoliotics (N = 161)	Controls (N = 100)
None	33 (20%)	14 (14%)
Rarely (1-5 times in whole life)	30 (19%)	25 (25%)
Occasionally (few days a year)	38 (24%)	36 (36%)
Frequently (few days a month)	32 (20%)	19 (19%)
Daily	28 (17%)	6 (6%)
Visited doctor for back pain	38 (24%)	30 (30%)
Hospitalized for back pain	9 (6%)	16 (16%)

Frequent or daily backache was experienced by 37 per cent of the patients in 1978. That incidence was greater than in the control group (25 per cent) and more than reported in 1968 (31 per cent). There was no correlation between the type and severity of curve and symptoms in the back except for patients with thoracolumbar curves. We compared the responses given by 148 patients seen in 1978 with their responses in 1968. The percentage of frequent or daily backache was the same in all groups except for the patients with thoracolumbar curves, in whom the incidence increased from 37 per cent in 1968 to 52 per cent in 1978.

Survey of Roentgenograms

The current roentgenograms of the 120 patients for whom they were available were compared with roentgenograms made between 1932 and 1948 and with those made in 1968. Each roentgenogram was evaluated for progression of the curve. In the past ten years, the major curves progressed an average of 3.9 degrees. Forty-four curves (37 per cent) increased by 5 degrees or more, seventy-two curves (60 per cent) remained unchanged, and three curves (3 per cent) decreased by more than 5 degrees. The thoracic and lumbar components of combined curves were counted as separate curves.

The thoracic curves increased an average of 3.1 degrees during the period from 1968 to 1978. Curves in

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TABLE

DATA SUMMARY BY

Type of Curve	Age* (Yrs.)	Sex (F/M)	Height* (cm)	Arm Span† (cm)	Length of Follow-up (Yrs.)	Visible Deformity When Dressed (No.)	Psychosocial Problems (No.)	Physical Limitation (No.)
Thoracic	52.7 (42-65)	43/16	155.7 (142.2-167.6)	162.6 (144.8-175.3)	39.8 (31-51)	42 (72%)	15 (25%)	7 (12%)
Combined	53.6 (43-65)	38/4	156.7 (147.3-170.1)	162.3 (144.8-177.8)	39.0 (31-51)	30 (71%)	10 (24%)	5 (12%)
Thoracolumbar	52.8 (45-66)	17/2	154.4 (147.3-162.5)	161.0 (152.4-166.6)	39.0 (31-51)	11 (58%)	5 (26%)	3 (16%)
Lumbar	52.9 (43-70)	38/3	161.0 (147.3-177.8)	167.4 (147.3-185.4)	39.4 (31-59)	19 (46%)	4 (10%)	4 (10%)

* Based on seventy-six patients who returned for physical examination.
† Based on sixty-nine patients with complete pulmonary-function testing.
‡ Based on 120 patients with current roentgenograms.
§ Based on ninety-one patients with current roentgenograms and 1968 roentgenograms.

seven patients (28 per cent) increased by more than 5 degrees in the ten-year interval (Fig. 1). Curves that measured between 50 and 80 degrees in 1968 increased an average of 11.3 degrees during the ten-year interval, whereas the curves that were less than 50 degrees or larger than 90 degrees tended not to progress. The thoracolumbar curves progressed an average of 3.3 degrees during the ten-year period (Fig. 3). The largest progression occurred in one curve that measured 90 degrees in 1968 and 108 degrees in 1978. At the lower end of this patient's curve there was a marked translatory shift between the third and fourth lumbar vertebrae.

In the combined curves, the thoracic component increased an average of 3.7 degrees in the ten-year interval (Fig. 2). In eleven patients (39 per cent) the thoracic component increased by more than 5 degrees since 1968, while

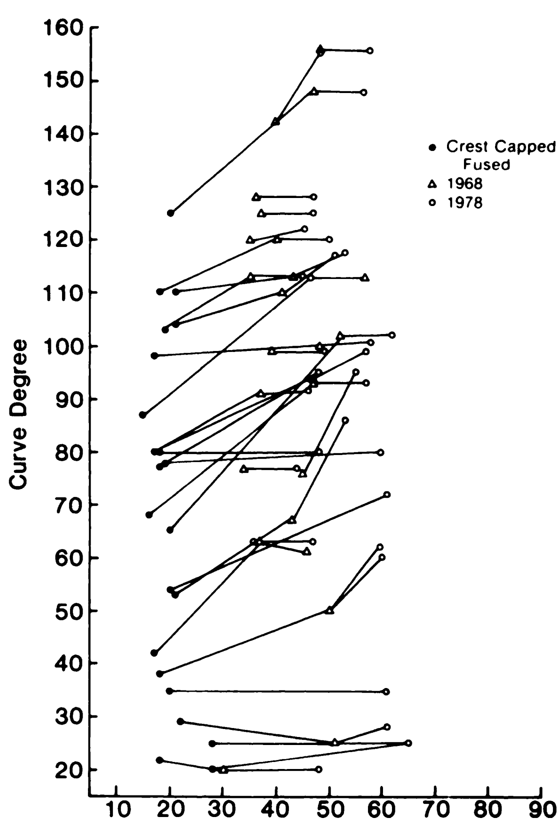

FIG. 1

Progression of the thoracic curves.

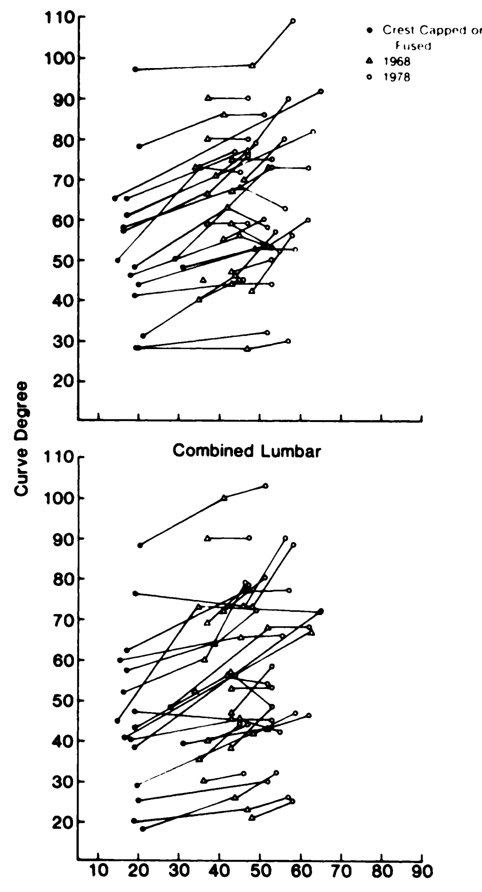

FIG. 2

Progression of the combined curves.

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II

TYPE OF CURVE

Never Married (No.)	Frequent or Daily Backache (No.)	Tender Back* (No.)	Size of Curve‡ (Degrees)	≥5-Degree Increase in Curve in 10 Yrs.§ (No.)	Osteoarthritis‡ (No.)	Diastolic Blood Pressure >100 mm Hg* (No.)	Shortness of Breath Limiting Activity (No.)
8 (14%)	15 (25%)	10 (42%)	92.4 (20-156)	7 (28%)	7 (18%)	2 (8%)	24 (41%)
3 (7%)	18 (43%)	10 (40%)	67.3 (30-109) 61.2 (25-103)	11 (39%) 14 (50%)	19 (56%)	2 (8%)	16 (38%)
2 (11%)	10 (52%)	2 (33%)	72 (45-145)	3 (30%)	7 (50%)	0	3 (16%)
4 (10%)	17 (42%)	12 (57%)	36.4 (15-78)	9 (32%)	13 (38%)	1 (5%)	4 (10%)

in fourteen patients (50 per cent) no progression was noted. In three patients (11 per cent) the thoracic component improved by 5 degrees or more during the decade. The lumbar component increased an average of 5.8 degrees (Fig. 2). In fourteen patients (50 per cent) the lumbar component increased by 5 degrees or more in the ten-year interval, while in fourteen patients (50 per cent) it did not progress. Interestingly, lumbar curves that measured between 50 and 74 degrees in 1968 progressed 7.8 degrees, which is more than the group average of 5.8 degrees.

Nine curves progressed disproportionately. In two patients the thoracic curve progressed more than the lumbar component, while in seven the lumbar curve increased more than the thoracic curve.

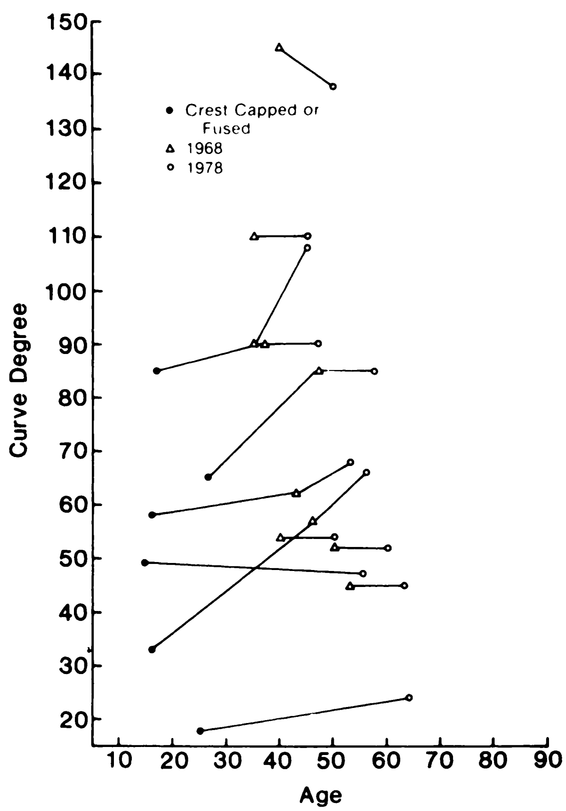

FIG. 3

Progression of the thoracolumbar curves.

In patients with a lumbar curve, it increased an average of 3.3 degrees during the ten-year period (Fig. 4). The curves of thirteen patients that measured less than 30 degrees in 1968 increased an average of 2.5 degrees during the ten-year period, while the remaining curves of more than 30 degrees progressed an average of 4.0 degrees since 1968.

On roentgenographic evaluation, twelve patients (35 per cent) with lumbar curves, five patients (15 per cent) with combined curves, and five patients (42 per cent) with thoracolumbar curves demonstrated a marked translatory shift between two vertebral segments. This represents five additional patients in whom translatory shifts developed since 1968. The shift took place at the lower end of the curve or at the transitional vertebrae and usually was responsible for curve progression. Vertebral shifts were most severe in the thoracolumbar curves.

Osteoarthritic changes were observed in the spines of forty-six (38 per cent) of the 120 patients. These changes ranged from minimum osteophyte formation and mild intervertebral disc-space narrowing to moderate facet-joint sclerosis and, rarely, to severe changes with spontaneous

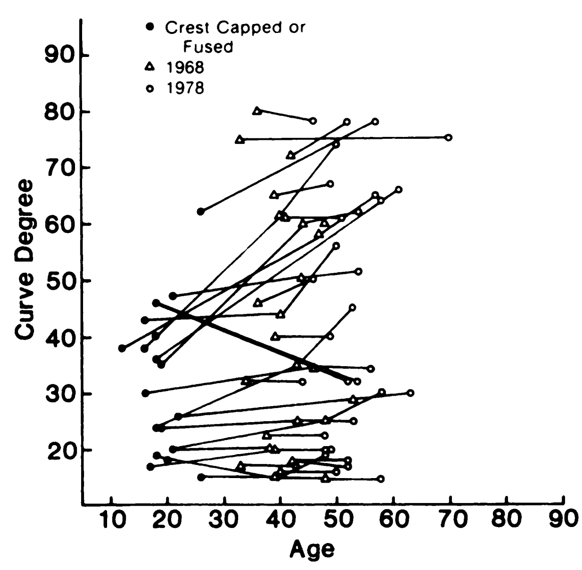

FIG. 4

Progression of the lumbar curves.

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TABLE III

RELATIONSHIP BETWEEN PULMONARY FUNCTION TESTS AND TYPES OF CURVES IN SIXTY-NINE UNTREATED PATIENTS

Curve Type	Age (Yrs.)	Curve (Degrees)	FVC*†	FEV_1*†	FEV_1/VC*	$FEF_{25-75\%}$*	PF*†	DCO*†	SBO_2*	pH	Po_2	Pco_2
Thoracic (16 women, 4 men)												
Mean	54	98	65	59	91	40	61	74	2.4	7.45	77	36
± S.E.M.	±5	±34	±19	±19	±11	±20	±20	±16	±1.7	±0.03	±9	±3.3
Range	45-65	25-156	33-104	28-100	65-108	12-101	32-94	39-96	0.8-8.0	7.40-7.55	62-90	28-42
Lumbar (19 women, 1 man)												
Mean	53	44	107	95	88	71	91	90	1.1	7.44	89	35
± S.E.M.	±5	±22	±18	±19	±9	±23	±22	±14	±0.06	±0.03	±9	±2
Range	46-61	19-78	59-148	38-120	64-100	33-119	61-146	70-109	0.3-2.8	7.4-7.49	79-108	30-40
Thoracolumbar (6 women)												
Mean	51	91	101	93	92	68	84	81	1.1	7.43	84	34
± S.E.M.	±4	±30	±14	±18	±16	±33	±13	±2	±0.3	±0.02	±8	±1
Range	47-56	54-138	84-118	68-110	72-117	26-109	73-105	80-84	0.8-1.8	7.41-7.44	78-90	32-37
Double major (22 women, 1 man)												
Mean	52	68	95	85	89	57	88	90	1.9	7.45	85	34
± S.E.M.	±7	±20	±19	±20	±10	±21	±33	±17	±2.2	±0.02	±10	±4
Range	43-62	32-109	60-128	50-124	72-100	12-93	42-147	63-108	0.3-4.0	7.42-7.49	71-100	26-40

* FVC = forced vital capacity, FEV_1 = forced expiratory volume in one second, VC = vital capacity, $FEF_{25-75\%}$ = forced mid-expiratory flow (between 25 and 75 per cent of forced vital capacity), PF = peak flow, DCO = diffusing capacity using carbon monoxide, single breath, and SBO_2 = single-breath oxygen.

† Values given are percentages of predicted values.

intervertebral fusion at the concavity of the curve. The osteoarthritic changes were mild in thirty-one (67 per cent) of the forty-six patients, moderate in ten patients (22 per cent), and severe in five patients (11 per cent). Thoracic disc calcification was present in seven patients (6 per cent). The severity of the vertebral osteoarthritic changes appeared to be unrelated to the degree and type of spinal curvature (Table II). We noted a marked shift between two vertebral segments (translatory shift), usually at the transitional vertebrae, on the roentgenograms of twenty-two patients (18 per cent). Only one patient, with severe osteoporosis, had collapse of one lumbar vertebral body and an increase in the spinal curve.

TABLE IV

MORTALITY (1968 TO 1978)

Case	Age at Death (Yrs.)	Curve at Last Visit (Degrees)	Cause of Death*
1	40	50/35, combined	Unknown
2	72	36, lumbar	C.O.P.D., A.S.C.V.D.
3	49	67/41, combined	Cervical cancer (uterine)
4	54	142, thoracic	Cor pulmonale, heart failure
5	48	105, thoracic	Rheumatic heart disease, congestive heart failure
6	60	51, thoracic	Diabetes, coronary thrombosis
7	47	75, thoracolumbar	Unknown (in mental institution, deaf)
8	40	136, thoracic	A.S.C.V.D., myocardial infarction
9	50	40, lumbar	Unknown
10	57	53, lumbar	A.S.C.V.D., myocardial infarction
11	63	82/45, combined	A.S.C.V.D., congestive heart failure, respiratory arrest
12	57	85, lumbar	Scleroderma, congestive heart failure
13	56	65/41, combined	A.S.C.V.D., myocardial infarction
14	40	31, lumbar	Unknown
15	45	80, thoracic	Suicide
16	48	37/32, combined	Breast cancer

* C.O.P.D. = chronic obstructive pulmonary disease and A.S.C.V.D. = atherosclerotic coronary vascular disease.

Mortality

Thirty-three of the 219 patients who could be traced had died; this is a mortality rate of 15 per cent. For comparison, the predicted death rate of a group of people from the general population matched as to sex and date of birth is 17 per cent as calculated from life-insurance tables[25]. The age at death ranged from eighteen to seventy-seven years, with an average of 49.3 years. Seventeen of the deaths had occurred prior to 1968 and have been described previously[5]. Death certificates and information from postmortem examinations were obtained for all but six patients. Cor pulmonale secondary to scoliosis was implicated as the cause of death in only one patient (Case 4, Table IV). When last examined in our clinic, nineteen of the thirty-three patients had curves of less than 60 degrees, five had curves of 60 to 80 degrees, four had curves of 80 to 100 degrees, and five patients had curves of more than 100 degrees.

Physical Findings

Of the seventy-six patients who were examined in 1978, the diastolic blood pressure was less than 100 millimeters of mercury in seventy-one and more than that in five. Two patients were taking digitalis: the patient who had had a coronary bypass operation and the one with a myocardial infarction. Wheezes were heard in a few pa-

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tients, several of whom were heavy cigarette smokers. There were no gross motor or sensory deficits. The straight-leg-raising test was negative in all patients, including those with a history of sciatica. Limb lengths were equal to within one centimeter in each patient. Eight patients (11 per cent) were shorter than 152 centimeters, and five of these eight patients had thoracic curves. The average arm span was 163.3 centimeters, and the average height was 157 centimeters.

Forty-two patients (55 per cent) had no tenderness in the back, whereas thirty-four patients (45 per cent) had some tenderness in one or more areas, and those patients also had one or more of the following: localized tenderness at the concavity of the curve, a positive instability test[14] at the junction between two curves or in the region of the lumbar spine, diffuse paraspinous tenderness, tenderness over the rib hump, and tenderness in the interscapular and suprascapular regions. Body alignment was measured with a plumb line held at the tip of the spinous process of the seventh cervical vertebra; the lateral displacement was less than 3.5 centimeters in all patients.

Pulmonary Symptoms and Function

A total of forty-seven patients (29 per cent) complained of shortness of breath that limited their activities, but only four of those patients (2.5 per cent) had severe dyspnea after walking two blocks or climbing one flight of stairs.

Sixty-nine of the seventy-six patients who returned to Iowa City for evaluation had extensive pulmonary-function studies consisting of determinations of arterial blood gases, spirometry (vital capacity, forced vital capacity, forced expiratory volume in one second, ratio of forced expiratory volume in one second to forced vital capacity, forced mid-expiratory flow [between 25 and 75 per cent of forced vital capacity]), flow-volume loops, lung volumes by body plethysmography, airways resistance, specific conductance, functional residual capacity by helium dilution, diffusing capacity, and single-breath oxygen. All of the lung studies were carried out on a Collins body plethysmograph and a Collins computerized modular analyzer (Collins, Inc., Braintree, Massachusetts) equipped with a Hewlett-Packard X-Y recorder. An IL-713 blood-gas analyzer was utilized to obtain the arterial pH, P_{CO_2}, P_{O_2}, bicarbonate radical, total carbon dioxide, and base excess.

Twenty-four (41 per cent) of the fifty-nine patients with thoracic curves complained of shortness of breath that limited their activities, while eight (14 per cent) of these patients noted dyspnea after walking one to three blocks or after climbing one flight of stairs. Twenty patients (four men and sixteen women) in this group had pulmonary function tests; their average curve was 98 degrees, with a range of 25 to 156 degrees (Table III). The mean forced vital capacity was 65 per cent, the mean forced expiratory volume in one second was 59 per cent, the mean forced expiratory volume in one second-vital capacity ratio was 91 per cent, and the mean forced mid-expiratory flow (between 25 and 75 per cent of forced vital capacity) was 40 per cent. Thirteen (65 per cent) of the twenty patients had a vital capacity of less than two liters. One of the two patients with a thoracic curve of less than 60 degrees had a vital capacity of less than 75 per cent (Fig. 5). Fifteen (83 per cent) of the eighteen patients with curves larger than 60 degrees had a vital capacity of less than 75 per cent, and eleven (61 per cent) of these eighteen patients had a vital capacity of less than 65 per cent. All of the eleven patients who complained of shortness of breath had a vital capacity of less than 75 per cent; however, of the sixteen patients whose vital capacity was less than 75 per cent, only eleven (69 per cent) complained of shortness of breath.

Pulmonary symptoms and diminished vital capacity correlated well with the severity of the thoracic curve. Of the sixteen patients with a thoracic curve larger than 80 degrees, all but one had a vital capacity of less than 75 per cent and all but five had a vital capacity of less than 65 per cent. Patients with curves between 100 and 140 degrees had an average vital capacity of 60 per cent, with a range of 43 to 70 per cent. All three patients with a thoracic curve that was larger than 140 degrees had less than 40 per cent of predicted vital capacity.

Sixteen (38 per cent) of the forty-two patients with combined curves complained of shortness of breath that limited their activity. Twenty-three patients (one man and twenty-two women) in this group had pulmonary function testing; the average thoracic curve component of the double major curve measured 68 degrees, with a range of 32 to

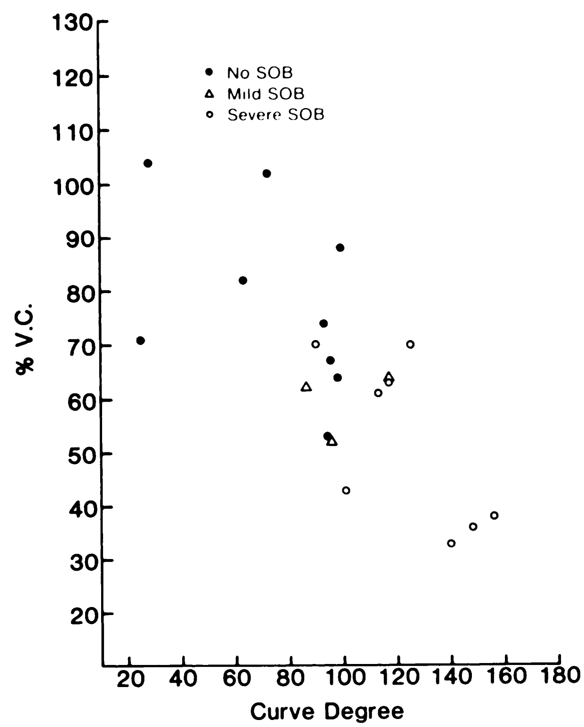

FIG. 5

Per cent of predicted vital capacity plotted against degree of curvature for the twenty patients with thoracic curves who had pulmonary function testing. Pulmonary symptoms also are plotted (SOB = shortness of breath).

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109 degrees (Table III). The mean forced vital capacity was 95 per cent, the mean forced expiratory volume in one second was 85 per cent, the mean forced expiratory volume-vital capacity ratio was 89 per cent, and the mean forced mid-expiratory flow was 57 per cent. Of these twenty-three patients who had pulmonary function testing, none of the nine with a curve of less than 60 degrees had a vital capacity of less than 75 per cent. Two of the fourteen patients with a thoracic curve larger than 60 degrees had a vital capacity of less than 75 per cent. The vital capacity was greater than 75 per cent in twenty-one patients (91 per cent) and less than 65 per cent in only two patients (9 per cent). Both patients with a vital capacity of less than 75 per cent complained of shortness of breath. Two of the nine patients who complained of shortness of breath had a vital capacity of less than 75 per cent. These patients had fewer pulmonary symptoms and better vital capacities than the patients with thoracic curves (Fig. 6). We found no correlation between the decrease in vital capacity and the severity of the thoracic curve.

Three of the nineteen patients (16 per cent) with a thoracolumbar curve complained of shortness of breath that limited their activities. The six women who had pulmonary function testing had an average curve of 91 degrees, with a range of 54 to 138 degrees (Table III). The mean forced vital capacity was 101 per cent, the mean forced expiratory volume in one second was 93 per cent, the mean forced expiratory volume in one second-vital capacity ratio was 92 per cent, and the mean forced mid-expiratory flow was 68 per cent. None of the six patients who had pulmonary function studies had a vital capacity of less than two liters, or 84 per cent of the predicted value (Fig. 7).

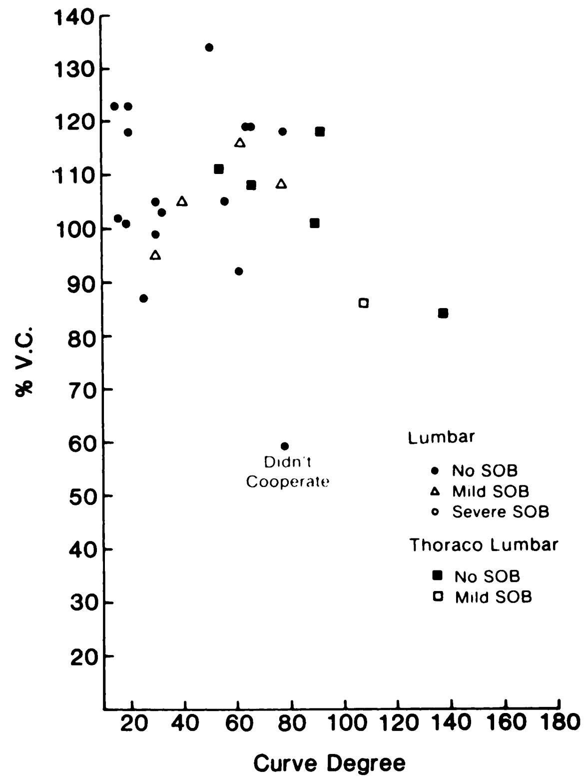

Fig. 7

Per cent of predicted vital capacity plotted against degree of curvature for the six patients with thoracolumbar curves and the twenty patients with lumbar curves who had pulmonary function testing. Pulmonary symptoms also are plotted (SOB = shortness of breath).

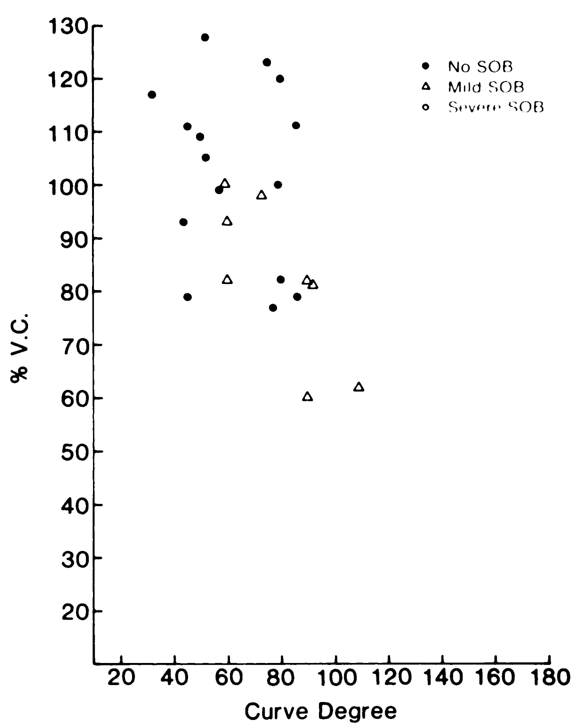

Fig. 6

Per cent of predicted vital capacity plotted against degree of thoracic curve component for the twenty-three patients with combined curves who had pulmonary function testing. Pulmonary symptoms also are plotted (SOB = shortness of breath).

Four (10 per cent) of the forty-one patients with lumbar curves complained of shortness of breath that limited their activity. Only one patient had a vital capacity of less than 75 per cent, but this patient did not complain of shortness of breath. Of the other patients who complained of shortness of breath, none had a vital capacity of less than 75 per cent.

Twenty patients with lumbar curves (nineteen women and one man) had pulmonary function testing; their average curve was 44 degrees, with a range of 19 to 78 degrees (Table III). The mean forced vital capacity was 107 per cent, the mean forced expiratory volume in one second was 95 per cent, the mean forced expiratory volume in one second-vital capacity ratio was 88 per cent, and the mean forced mid-expiratory flow was 71 per cent.

When the pulmonary function data were analyzed (Table III), a significant correlation was found between a reduction in the vital capacity (and forced expiratory volume in one second) and increasing severity of the thoracic curve (Fig. 8). Similar results were obtained when the Pao_2 was plotted against the severity of the curve (Fig. 9). The deleterious effect of smoking on pulmonary function also is demonstrated in Figures 8 and 9. Marked diminu-

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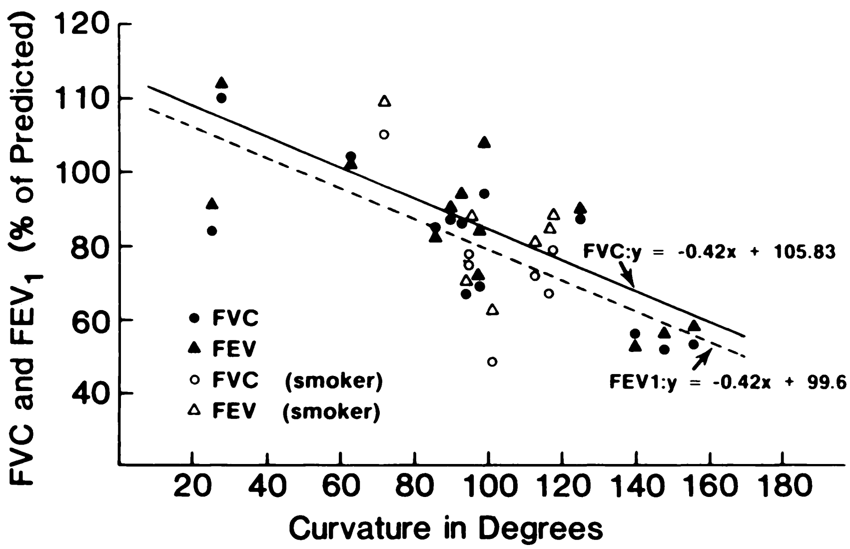

FIG. 8

Relationship between forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and size of the curve in twenty patients with thoracic scoliosis, using a line of regression.

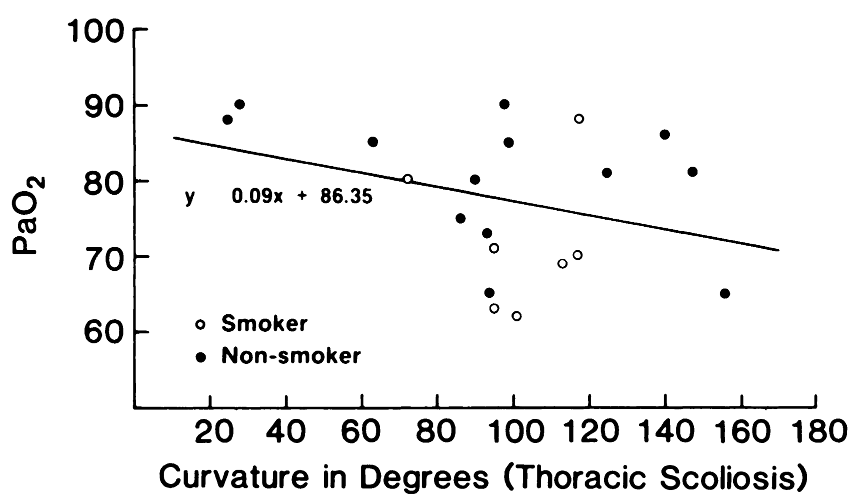

FIG. 9

Relationship between PaO_2 and size of the curve in twenty patients with thoracic scoliosis, using a line of regression.

tion of pulmonary function in a non-smoker did not occur until the thoracic curve approached 100 to 120 degrees. The pattern was uniformly that of restrictive lung disease. A noteworthy fact is that there was no correlation between spirometric results, pulmonary symptoms, and severity of the curve in patients with combined, thoracolumbar, or lumbar curves.

Discussion

In 1968 Nachemson, and Nilsonne and Lundgren, published long-term follow-up studies that expressed a grim prognosis for patients with untreated scoliosis. Nachemson reported a thirty-eight-year follow-up of 130 patients with untreated scoliosis. Thirty per cent claimed disability because of their deformity. There was a 100 per cent increase in the mortality rate compared with the general population, and sixteen of the twenty deaths were due to cor pulmonale. Thirty-seven per cent of the patients had constant backache, and 14 per cent complained of cardiopulmonary symptoms. It is important to note that only fifty-nine patients (45 per cent) in Nachemson's study had idiopathic scoliosis. The remainder included patients with congenital scoliosis, paralytic scoliosis, scoliosis secondary to tuberculosis, neurofibromatosis, and other miscellaneous diseases. Only twelve patients were seen in the follow-up study. Of the sixteen deaths due to cor pulmonale, only three occurred in patients with idiopathic scoliosis. Although no roentgenograms were available, Nachemson postulated that the constant backache in these patients probably was due to osteoarthritis.

Nilsonne and Lundgren reported a fifty-year follow-up of 113 patients. This group had a mortality rate that was twice the rate in the general population. Sixty per cent of the deaths were attributed to cardiopulmonary disease. Of

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the living patients, one-half were unable to work, 76 per cent of the women were unmarried, 90 per cent of all patients had back symptoms, 30 per cent were on disability pensions for back pain or scoliosis, and seventeen were disabled but not on pensions. Nilsonne and Lundgren had no roentgenograms to ascertain the etiology of the scoliosis in their patients. In addition, it was uncertain if any of the patients were examined on follow-up.

The recent long-term study by Fowles et al. was based on sixty-five of 117 patients who were followed for an average of twenty-three years. Ten patients had died. Twenty-two per cent were unemployed, 40 per cent had intermittent backache and 22 per cent had frequent backache, 9 per cent were on disability pensions, and 63 per cent of the women were unmarried. The study included patients with idiopathic scoliosis, paralytic scoliosis (secondary to poliomyelitis), congenital scoliosis, and kyphosis (one patient). Only twenty-four (44 per cent) of the fifty-five living patients had idiopathic scoliosis. It is unclear why the authors did not study their patients according to etiology and curve pattern, since it is well known that the prognosis of scoliosis varies according to the etiology. The various natural histories of curves with different etiologies, as well as with associated problems, may have a significant bearing on the ability of patients to meet the demands of daily life, work, and so on[2,3,17,27].

In idiopathic scoliosis, each curve pattern has its own particular characteristics and predicted course[4,5,11,23]. For the reasons discussed, it is impossible to make valid comparisons between the preceding studies and ours, which in contrast to all the others consists solely of patients with adolescent idiopathic scoliosis.

Although four (3 per cent) of our patients were on disability pensions, no one implicated scoliosis as the cause. The variety of occupations and hobbies certainly was not limited in our group, regardless of the curve pattern. Eighty-nine per cent of our patients were married. All of these findings are in sharp contrast with the results of Nachemson, Nilsonne and Lundgren, and Fowles et al.

Pulmonary function tests were carried out on sixty-nine patients, of whom nineteen (28 per cent) had a vital capacity of less than 75 per cent of normal. Of these nineteen patients, sixteen (84 per cent) had thoracic curves and thirteen (68 per cent) complained of shortness of breath. Only thirteen (50 per cent) of twenty-six patients who complained of shortness of breath had a vital capacity of less than 75 per cent of normal.

There was a significant correlation between reduction in vital capacity and forced expiratory volume in one second and increasing severity of the curve only in patients with thoracic curves. In addition, marked reduction of pulmonary function in the non-smokers did not occur until the thoracic curve approached 100 to 120 degrees.

The 15 per cent mortality rate in our series is similar to the 17 per cent predicted mortality rate of a matched group of people from the general population[25] but differs significantly from the often-quoted figures of Nachemson and of Nilsonne and Lundgren. When the causes of death were analyzed[5] (Table IV) on the basis of death certificates and postmortem examinations, cor pulmonale secondary to scoliosis could be implicated as a cause of death in only one of thirty-three patients.

Twenty-four per cent of our patients sought the aid of a physician for backache, compared with 30 per cent for our control group. Only 6 per cent of our patients required hospitalization for backache, compared with 16 per cent of the control group. Two of our patients gave a history of sciatica, and one patient had surgery for a suspected herniated nucleus pulposus.

Tenderness of the back on physical examination could not be related to the type of curve or to the severity of osteoarthritic changes except for the instability test[14] in the areas of translatory shift in the lumbar and thoracolumbar curves.

Forty-six (38 per cent) of the 120 patients with current roentgenograms exhibited changes of osteoarthritis. In two-thirds of the patients the osteoarthritic changes were mild. They were most common in the lumbar component of combined curves (41 per cent), followed by thoracolumbar curves (29 per cent), lumbar curves (18 per cent), and thoracic curves (5 per cent). Moderate osteoarthritic changes were seen in ten (22 per cent) of the forty-six patients, being most common in the lumbar curves. Five patients had a spontaneous fusion in the concavity of the curve (thoracic, one; thoracolumbar, two; and lumbar, two). None of the osteoarthritic changes were correlated with the severity of the curve or with backache.

Disc-space calcifications were seen in two patients with thoracic curves (5 per cent) and in five thoracic components of combined curves (15 per cent). The significance of this finding is not known.

The forty-one patients who responded by questionnaire alone were evaluated separately. Twenty-one had thoracic curves; seven, lumbar curves; eight, combined curves; and five, thoracolumbar curves. Based on current symptoms in the back and on curve measurements made as late as 1968, these patients proved to be comparable to the over-all group but had fewer back complaints. Patients who could not be found or who were located but refused to participate in the study possibly had fewer symptoms, as verified in other long-term studies[19].

Five patients had spine fusions as adults, three prior to 1968 and two since then. All five patients had complications from surgery, including rod breakage and pseudarthrosis, and four of the five continued to have back pain. Although there have been many favorable reports on surgery in adult scoliosis patients, morbidity rates may be as high as 40 per cent[6,13,22]. Until long-term studies prove that the operative benefits exceed the risks, surgery in the adult must be used only when all conservative methods have failed.

Before recommending so-called corrective surgery in patients with scoliosis, it is important to consider the effect, if any, that surgery has on pulmonary function and

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the relief of back pain. There have been many short-term evaluations concerning the effects of spine fusion on pulmonary function; however, the conclusions all are controversial[8,10,12,15,16,24,26-28]. Only two long-term studies are available on the results of fusion in scoliosis. Moskowitz et al. located sixty-one (55 per cent) of 110 patients who had undergone a fusion between 1947 and 1957. Low-back pain in this group was found to be no more frequent than in the general population. However, they reported a 57 per cent incidence of neck pain. Ginsburg et al. studied 147 patients fused by Goldstein and found that those with a fusion down to the fourth or fifth lumbar vertebra had a 45 per cent incidence of low-back pain, and some had disabling lumbosacral symptoms, ten or more years after fusion. It will be most helpful to see the outcome of these two groups of patients over the next ten to twenty years, including the results of complete pulmonary-function studies.

Conclusions

Backache was slightly more common in patients with scoliosis than in the general population, but it was not disabling. Furthermore, backache was unrelated to the presence or absence of osteoarthritic changes or to the severity of the curve. The cosmetic deformity of scoliosis was better accepted by the older patients, but there was no correlation between the location or degree of the curve and the psychosocial effects.

Many idiopathic scoliotic curves will continue to increase slowly during the patient's adult life — particularly thoracic curves measuring between 50 and 80 degrees. Scoliosis affected pulmonary function only in patients with thoracic curves and did not cause significant limitations in the vital capacity and forced expiratory volume in one second until the curve approached 100 to 120 degrees. The pattern in the non-smokers was uniformly characteristic of restrictive lung disease.

There is much to learn regarding the basic biological mechanisms responsible for idiopathic scoliosis. Ultimately, a better understanding of the disease process may lead to more effective treatment. At present, the methods available for the management of the scoliotic deformity are expensive and time-consuming. Patients whose curves are unresponsive to bracing are treated surgically, but that sacrifices spinal mobility. Before undertaking the risks of surgical intervention, one must be aware of the long-term results of the surgical treatment when compared with the natural history of the disease.

On the basis of the present study, we recommend that progressive thoracic curves reaching 50 degrees at skeletal maturity should be fused. Since fusions to the fourth and fifth lumbar vertebrae may result in a high incidence of backache ten years later, fusions of the lumbar component of a double major or lumbar curve are of questionable value considering the fact that the patients in our study, all untreated, have led normal lives. Patients with double major or lumbar curves that are not severe, if skeletally immature, should be treated by bracing techniques since with aging they will not be limited by poor pulmonary function or backache.

Patients with thoracolumbar curves present a special problem. With increasing severity of the curve, they do not have decreased pulmonary function but they do have a marked degree of cosmetic deformity and increasing, though not disabling, back pain (often associated with a translatory shift of the vertebrae). Surgical treatment of these curves when they reach 50 to 60 degrees therefore is justified.

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Treatment of Displaced Segmental Radial-Head Fractures

LONG-TERM FOLLOW-UP

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ABSTRACT: **We did a retrospective study of forty segmental fractures of the radial head in thirty-nine patients. Good results were achieved in twenty of thirty-four fractures with non-operative treatment. In six patients the radial head was excised totally and in only one was a good result achieved. The average follow-up was 10.0 years. Only rarely was there deterioration of the short-term results. The prognosis was not affected by the extent of the depression, the size of the fragment, or the degree of comminution. We concluded that the only indication for operation in this type of fracture is a loose fragment in the joint.**

Many authors have written on the subject of fractures of the radial head, and it generally has been agreed that segmental fractures of the radial head with less than two millimeters' displacement of the fragments (Mason's Type I)[21] should be treated non-operatively. When there is comminution of the entire radial head (Mason's Type III)[21], all have agreed that total excision of the radial head is indicated. However, the treatment of segmental fractures in which the fragment is displaced or depressed, or both, by at least two millimeters and the fragment includes at least one-quarter of the radial head (Mason's Type II)[21] is a matter of controversy.

Some have advocated non-operative treatment while others, including the authors of most textbooks, have advocated prompt excision. Others have excised the radial head only if the fragment involved more than a specified amount of the radial head or the fragment was displaced more than a certain amount. Recently, open reduction and internal fixation has been advocated in selected patients[23,27].

This study was undertaken in order to ascertain the results of operative and non-operative treatment in a large series of patients with isolated Mason Type-II[21] radial-head fractures evaluated at long-term clinical follow-up.

Materials and Methods

We reviewed the cases of all patients seen at Saint Francis Hospital in Evanston, Illinois, from 1956 to 1978. Of these, thirty-nine patients with forty fractures fulfilled the required criteria: (1) the fragment was displaced or depressed, or both, by at least two millimeters and involved at least one-quarter of the radial head (Figs. 1-A through 2-B); (2) there was no associated ipsilateral fracture, dislocation, or injury; (3) the original roentgenograms were available to confirm the size and amount of depression of the fragment; and (4) a minimum follow-up of one year was recorded.

All patients, except four who answered a detailed questionnaire, were personally re-examined by one of us (G. K. M.). Non-operative treatment consisted of three weeks of wearing a long cast after which range-of-motion exercises were prescribed, with the exception of one patient who was started on immediate range-of-motion exercises. In six patients total radial-head excision was performed in an average of 3.5 days (range, one to six days)

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