1959), a finding which we have confirmed in this study. This elevation could either wholly or partly account for the longer and heavier thrombi found in patients with myocardial infarction.

We do not know whether the factor or factors responsible for the development of large thrombi were present before infarction or merely reflect the results of infarction. It appears that the latter is more likely. Nevertheless, it is interesting to speculate whether this propensity to abnormal *in vitro* thrombosis after myocardial infarction might be associated with the tendency of these patients to subsequent thrombotic episodes.

Our results clearly indicate that there is a significant increase in the incidence of platelet abnormalities in patients with myocardial infarction when compared with control subjects over the age of 40 years. Again we cannot be sure whether these findings relate to a state existing before infarction or are wholly or in part a sequel to myocardial necrosis. However, we have demonstrated that there is a definite tendency for both the frequency of spontaneous platelet aggregation and thrombus size to increase with age in apparently healthy subjects. These findings suggest that the factor or factors responsible for these phenomena are present to some extent before the clinical event, and that coronary thrombosis could result from an exaggeration of this trend.

The overall frequency of platelet abnormality was similar in patients with myocardial infarction whether or not they were receiving anticoagulant therapy (Table II). Two explanations for this finding should be considered. First, it could be that in anticoagulated patients the initial overall frequency of platelet abnormality was greater, and that this frequency has in fact been reduced by therapy. Alternatively, anticoagulants may have had little or no effect on platelet aggregation. On the other hand, there was a trend, though not statistically significant (Table II), for the snowstorm phenomenon to occur more often in anticoagulated patients (11.5%) than in those not receiving anticoagulant therapy (4.7%). At first sight this might suggest that anticoagulant therapy had enhanced platelet aggregation. This trend may, however, merely reflect the fact that those patients selected for anticoagulant therapy differed from those not given anticoagulants, possibly on the basis of more extensive infarction. It is apparent that the effect of oral anticoagulants on platelet aggregation in this *in vitro* system is inconclusive.

Summary

Fifty healthy subjects and 52 patients with myocardial infarction were investigated, the Chandler apparatus being used as an *in vitro* model for the study of thrombosis and platelet aggregation. It was found that thrombus weight and length increased with age in healthy subjects, and that both were markedly elevated in patients with myocardial infarction. Thrombus weight and length were less in patients receiving oral anticoagulant therapy, and both declined progressively with the passage of time after infarction. Plasma fibrinogen levels and thrombus weight showed a statistically significant correlation in both control subjects and in patients with myocardial infarction. No significant correlation between total serum cholesterol levels and thrombus weight was found.

Abnormal platelet aggregation was found to increase in frequency with age in healthy control subjects, and in patients with myocardial infarction it was significantly more common than in control subjects. The overall frequency of abnormal platelet aggregation was slightly less in those patients who had sustained their infarcts more than six weeks before the time of study. Patients receiving oral anticoagulants showed no significant decrease in the frequency of abnormal platelet aggregation, but a trend for the snowstorm phenomenon to occur more often in this group was noted.

This study has shown that the blood of patients with myocardial infarction shows a propensity to abnormal *in vitro* thrombosis and platelet aggregation. The possible significance of the findings is discussed.

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Changing Patterns of Fracture in the Dorsal and Lumbar Spine

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Major injuries are not new to this country, but their numbers are beginning to reach epidemic proportions with the coming of the motor-car society. Because changing causes of injury may be producing changing patterns of damage we have surveyed fractures of the dorsal and lumbar spine seen by the Accident Service at the Radcliffe Infirmary in the decade ending in 1957. Injuries to the cervical spine in this decade have already been surveyed (Taylor and Gleave, 1962). While injuries to the cervical spine often occur in isolation, fractures of the dorsal and lumbar vertebrae imply a transmission through and absorption by the body of a great deal of kinetic energy. Other parts of the body are more likely to transmit and to absorb force, and will be damaged in so doing. Consequently,

we have paid particular attention to the pattern of injuries suffered by the body as a whole and the way in which they impinge on the spinal injury. Further, and related to these multiple injuries, we have come to believe that the thoraco-

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lumbar junction no longer takes first place among sites of injury, and that mid-dorsal fractures are now more frequent than those at any other site in the dorsal and lumbar spine.

Material

A total of 250 patients with spinal fractures were admitted to hospital, forming approximately 1% of all patients with fractures. Injuries to the cervical spine numbered 95; the remaining 155 form the group of injuries to the dorsal and lumbar spine under consideration here. The case-notes were abstracted and the data entered on punch cards, from which the analysis was made.

The age and sex distribution of our patients (Fig. 1) conforms closely to the national pattern for fatal and serious casualties (Road Accident Statistics, 1960). Men in the third decade of life outnumbered those in any other decade by over 100%, and approximately half of these were motor-cyclists. There was a large sex difference in the proportions aged 50 and over, being 38% in females and 23% in males. Pre-existing bony disease of the spine contributing materially to the injury was thought to be present in six patients, five of them over 60. These conditions were osteoporosis, gross osteoarthritis, and Paget's disease.

FIG. 1.—Age and sex distribution of lumbar and dorsal spinal fractures.

Causes and Circumstances of Injury

Traffic accidents and falls, equally divided, caused 95% of the accidents (Fig. 2). As would be expected, motor-cycles, cars, and bicycles make up the vast majority of the traffic accidents. Two points are worth noting. First, motor-cycles outstrip cars in the absolute numbers of spinal injuries caused; in view of the large excess of cars over motor-cycles on the road, this confirms that motor-cyclists run an excessive risk. Secondly, the majority (over 60%) of the cars involved had

FIG. 2.—Causes of injury.

overturned. The safety harness for car travellers had not been introduced during the years of the survey. There are no mines in the area.

Types of Vertebral Fracture

The types of vertebral fracture are set out in Table I. As would be expected, about 90% (137 out of 155) were of the wedge or crush-in-flexion variety, the proportions being similar in males and females. One-third of the females and approximately one-half of the males involved in these wedge fractures had more than one vertebra injured. All except 10 of these fractures were in adjacent vertebrae. Three patients, all males in the fourth decade, had chip fractures of the upper thoracic bodies; none of these had spinal cord damage. There were six fractures involving the posterior elements only; the majority resulted from a fall backwards on to a beam or other firm object, causing direct trauma. One patient had an explosive or bursting variety of fracture, and this did not cause any spinal cord damage.

TABLE I.—Types of Vertebral Fracture

Wedge Fractures	Chip Fractures	Burst Fractures	Posterior Elements Only	Fracture Dislocations	Total
137	3	1	6	8	155

There were eight fracture-dislocations, all but one in men, and in six of these the spinal cord had sustained damage, confirming the grave prognosis carried by this type of injury. Fracture-dislocations occurred in two groups—one group of five in the upper and mid-dorsal region of the thoracic spine, and the other of three in the lower dorsal region. One patient in each group escaped spinal cord damage.

Multiple Fractures

The patients with wedge fractures form the only group large enough to enable firm conclusions to be drawn about the effect of age and of sex (Table II). There was a marked tendency for the multiple fractures to occur in the younger age-group independently of sex. In addition, there was an association between motor-cycle accidents and multiple fractures, 58% of this group having multiple fractures. Of the patients with spinal cord damage 67% had multiple fractures. When considering the patients without paraplegia, those with severe associated injuries had only a small proportion with multiple vertebral fractures in excess of the proportion without major associated injury (48% compared with 41%).

TABLE II.—Effect of Age and Sex in 137 Wedge Fractures

	Single	Multiple		Single	Multiple
Male	52	43 (45%)	Males above 50 ..	15	7 (32%)
Female	27	15 (36%)	Below 50	37	36 (49%)
Total	79	58	Total	52	43
Above 50	27	11 (29%)	Females above 50	12	4 (25%)
Below 50	52	47 (47%)	Below 50	15	11 (42%)
Total	79	58	Total	27	15

Most Frequently Injured Vertebrae

The vertebrae involved in the group as a whole are set out in Fig. 3. There are two peaks in the distribution of the fractures through the spine; one in the mid-dorsal region, and the other around the twelfth thoracic vertebra. This finding is at variance with the standard account, which recognizes only

the lower dorsal or thoraco-lumbar peak. As this was a surprising finding, the analysis was taken further in order to see what factors were preferentially associated with the mid-dorsal fractures.

FIG. 3.—Distribution of fractures through the spine.

The cases were divided into two groups by selecting for factors thought to imply more severe trauma. The cases concerned with multiple fractures, death, paraplegia, severe associated injuries, overturned cars, and motor-cycles were extracted. There were 105 patients in this group. The remainder were regarded as having suffered mild trauma only. The mid-dorsal fractures in the severe group now became easily the commonest, both T 6 and T 5 injuries occurring more often than T 12 injuries. The opposite was true in the mild trauma group, where T 12 fractures predominated. Within the severe trauma group there was no difference between the general distribution and that of a subgroup of 41 patients whose injuries were not due to traffic; however, when the patients over 50 were extracted and the distribution of their fractures was plotted in the same way a different picture emerged. The older patients formed a much larger fraction of the group subjected to mild trauma. In addition, even in the severe group in older patients the dorso-lumbar peak was rather larger than the mid-dorsal peak, when fractures at T 5, 6, and 7 were summed and compared with those at T 11, T 12, and L 1.

In order to throw further light on this difference two small groups were examined. First, the fracture-dislocations were studied. These fell into two approximately equal groups, centred on the mid-dorsal and thoraco-lumbar regions respectively. Secondly, the non-contiguous multiple fractures were analysed. These fell into two groups; one where only one intact vertebra separated the two or more which were fractured, and another group where the separation was wider than this. The first group was assumed to be of no special interest in this connexion as the trauma had been absorbed in one region of the spine only. The more relevant second group, with a wider separation, contained five patients. The vertebrae involved were as follows: T 5 with L 1; T 6 with T 11, T 12, L 1, and L 2; T 6 with T 11 and T 12; T 7 with L 1; T 9 with T 12. Ignoring the last of these, with a separation of two intact vertebrae only, it is striking that only combinations involving vertebrae in the two peaks of incidence are present in this small group. This is additional evidence that the two peaks of

incidence must correspond to the two regions of stress in the spine.

Spinal Cord Injuries

In this group there were 14 patients—just under 10% of the total. This figure contrasts strongly with the 40% of patients with fractures of the cervical spine who sustain spinal cord damage (Taylor and Gleave, 1962). Two-thirds of the group were under 30 years of age. Traffic accidents and falls contributed equally to these injuries, conforming to the proportions in the group as a whole. The distribution of fractures conforms to the overall pattern of two peaks, in the mid-dorsal and thoraco-lumbar regions respectively (Fig. 4). The correlation with fracture-dislocations has been previously mentioned. The sex distribution in no way departed from that of the series as a whole.

FIG. 4.—Distribution of fractures, both sexes, in paraplegics and in non-paraplegics with severe associated injuries.

Two patients in this group died, both having severe associated injuries, the deaths being primarily due to these injuries. In addition to the two who died, two more had severe head injuries, one of whom needed surgical exploration of the posterior fossa; the other also had a fracture of the femur. The fifth patient had a major chest injury. The paraplegic patients were approximately twice as likely to have severe associated injuries as those without damage to the spinal cord, having a higher proportion of multiple vertebral fractures than any other subgroup—namely, 67%.

Only two of the 14 spinal cord lesions were functionally incomplete, again contrasting markedly with those in the cervical spine, where well over 50% were incomplete (Taylor and Gleave, 1957). Both these patients had incomplete lesions when first seen, both had damage to the conus and cauda equina, and both were able eventually to walk. One had mild residual weakness of the ankles and the other had weakness of both legs and a mild disturbance of sphincter control.

Of the 10 surviving patients with complete lesions from the onset, all remained complete. Seven had lumbar puncture in the acute stage, and six of these showed a manometric block. The neurological levels corresponded in each with the known level of vertebral fracture. In only one was an exploration and decompression carried out, after a myelogram had revealed a block at the eighth thoracic level with compression fractures of T 3 and T 4; operation revealed fractures of the posterior elements in addition, with the spinal cord grossly intact.

Injuries causing damage to the spinal cord and roots were thus more often accompanied by death, by severe associated multiple injuries, by multiple vertebral fractures, and by fracture-dislocations than in the group as a whole. The inference, as might be expected, was that when the spinal cord was damaged the amount of force which these patients were subjected to was greater than when the cord escaped.

Severe Associated Injuries

As well as the five paraplegics with injuries coming into this category, there were 27 without spinal cord damage. The distribution of these through the body is set out in Table III. There seemed to be no correlation between the site of the associated injury and the vertebral level of the spinal injury.

TABLE III.—Severe Associated Injuries in 27 Out of 141 Non-paraplegic Patients

	Head	Jaws	Upper Limb	Chest	Abdomen	Pelvis	Lower Limb
Male	11	1	5	6	1	0	1
Female	0	0	1	2	0	1	0
Total	11	1	6	8	1	1	1

Deaths

In addition to the two deaths among the 14 patients with spinal cord injury there were four deaths in 141 patients without cord damage. Three of these deaths occurred in patients who had major associated injuries in addition to the vertebral injury. One woman aged over 80 died of bronchopneumonia, after multiple rib fractures, with a fractured humerus and clavicle, 12 days after injury. An 87-year-old man died of uraemia and bronchopneumonia 20 days after injury, at which he also sustained a mild head and major chest injury. The third patient was a young man of 20 who sustained a severe head injury and died, still in a decerebrate condition; seven months after injury. One patient died of tetanus; the spinal fracture was an incidental finding, probably caused by the tetanus.

Discussion

Several findings are surprising when considered against the weight of prevailing opinion (Bonnin, 1951; Watson-Jones, 1952; Perkins, 1958; Wiles, 1960; Nicol, 1962). This concerns the distribution of the fractured vertebrae and the different patterns of injury associated with the different types of fracture. In our series, first, multiple injuries are correlated preferentially with the mid-dorsal injury. Secondly, mid-dorsal fracture is an injury correlated with youth, and, thirdly, it is correlated with severe trauma. Fourthly, the evidence from the small but crucially important group of non-contiguous multiple fractures indicates that the mid-dorsal and thoraco-lumbar regions are the areas of stress concentration. Fifthly, the fact that the distribution of fracture-dislocations conforms to this double peak shows that rotary forces are concentrated in the same way as those bringing about simple compression or flexion. Sixthly, the paraplegic group, small though the numbers were, conformed also to these two peaks of distribution. We believe that these facts show that the mid-dorsal fracture is a common result of exposing the young male body to severe and often devastating forces.

Other explanations for these facts are possible; we have only pointed out correlations and inferred what we believe to be the most likely sequence of causal connexions between them. For instance, it is possible that older patients with mid-dorsal fractures have not survived the injury to reach hospital and to be included in this series. It is possible, too, that some fractures are missed when too much reliance is placed on x-ray examination for diagnosis. This error largely depends on the difficulty of obtaining adequate lateral views of the upper dorsal region and of the posterior elements of all dorsal and lumbar vertebrae. It is common, on exploring the fractured spine, to find bony damage unsuspected on x-ray examination. This bias—we think a small one—is inevitable in any series treated conservatively, as the present one was. We do not think it responsible for the large differences between this series and what has pre-

viously been regarded as the normal pattern of injury to the spine.

The area around Oxford from which these patients were gathered contained no mines, but heavy flows of fast-moving traffic run through it. Calculated on a population basis, the road deaths for the combined areas of Oxford and Oxfordshire in 1960 were not far from double the national average, and road casualties ran at 50% above the national average. This might seem to indicate a larger proportion of severe injuries than in other areas; if this is correct it might account for the failure to recognize the effects of severe injuries in other studies. We think that the key to the delayed recognition of these facts about the mid-dorsal fractures is contained in a statement by Holdsworth (1963): "Twenty years ago fractures of the spine were almost entirely the results of accidents occurring in heavy industry, particularly coal-mining, and were therefore geographically restricted. Now the incidence is almost equal throughout the country, for whereas spinal injuries in heavy industry are decreasing, those from road accidents are greatly increasing." From what we have already said it is probable that it is not simply the geographical pattern which is changing but the pattern of injury in the spine is changing with it.

It appears (Potter, 1965) as though in the past 10 years the pattern of injuries to the head is changing from an emphasis on motor-cycles to a predominance of motor-cars. If this is so for spinal injuries, a pattern differing from that recorded here might be expected to emerge in the future.

Summary

Fractures and dislocations of the spine formed 1% of all fractures dealt with by the Oxford Accident Service over the decade 1947–57, injuries to the thoracic and lumbar spines forming just over three-fifths of these.

Ten per cent of these patients suffered injury to the spinal cord and roots, the great majority being complete lesions.

One-fifth of all patients suffered severe associated multiple injuries.

Younger patients tended to incur more extensive fractures and more multiple injuries, and their vertebral fractures were concentrated at T 6.

Older patients tended to have milder injuries and less extensive fractures, and tended to fracture at T 12.

The majority of the patients with severe multiple injuries had mid-dorsal fractures.

Evidence is presented in favour of the existence of two separate areas of stress concentration at mid-dorsal and at thoraco-lumbar levels.

The pattern of injury to the thoracic and lumbar spine may be changing, probably because of the increasing importance of road accidents in their production.

Our thanks are due to our colleagues in the Oxford Accident Service, as this is largely a record of their work.

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