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EXPERIENCES WITH HIGH TETRAPLEGICS¹

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Abstract. Of the 1468 patients with traumatic spinal cord injury who were admitted to the Texas Institute for Rehabilitation and Research (TIRR) between 1959 and 1977, 67 patients were complete tetraplegics with motor levels of C4 and above. The age, sex, motor level, aetiology of injury, and initial and final vital capacity of these patients are analysed. A substantial gain in vital capacity was attained in all C4 motor tetraplegics regardless of their initial vital capacity. Twenty patients with motor levels of C3 and above have been admitted to TIRR since 1963. Five of these 20 C3 and above tetraplegics have had bilateral phrenic stimulators implanted. The mortality rates and causes of death in these groups of patients are presented. Survival curves are presented on 615 traumatic spinal cord injured patients as compared to a standard matched group. Survival curves are also presented for the two groups of high tetraplegics who were admitted to TIRR from 1963 through 1969 and from 1970 through 1977.

Key words: Tetraplegics; Vital capacity; Survival; Demographies.

Introduction

A REVIEW of 1468 patients with traumatic spinal cord injury who were admitted to the Texas Institute for Rehabilitation and Research (TIRR) since its inception in 1959 reveals that 4 per cent were admitted with a functioning motor level of C3 and above. These patients were apneic on admission. An additional 119 patients or 7 per cent were admitted with a functional level of C4. Through a review of the medical records of this group of patients, a list was compiled of the patients who were C4 motor complete and higher. All of these patients showed no greater change than two neurologic levels from admission to discharge; no cases of incomplete motor involvement or cases of central cord syndromes were included. No patients were included who were found to have a motor level lower than C4 at any time. Thus, the final list includes 67 patients who were admitted to TIRR at a complete C4 and above motor level.

Patients

The Texas Institute for Rehabilitation and Research in Houston, Texas, was established in 1959 and was an outgrowth of the Southwestern Poliomyelitis Respiratory Center. TIRR is a private, non-tax supported, 80-bed, specialised hospital which has received patients from 16 states and 18 foreign countries.

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TIRR does not receive all patients with spinal cord injury from any given area. The Regional Spinal Cord Injury Center at TIRR comprises two-thirds of the average inpatient census. We feel that our experience at TIRR with a large number of cases of spinal cord injury (1468 patients) over the past 18 years accurately reflects the various aetiologies and statistics which are involved in traumatic spinal cord injured patients.

Demographical Analysis

The 67 tetraplegic patients in this study include 59 males and eight females who have an age range of 4 to 70 years with an average age of 22.7 years at onset (Table I). Twenty patients have a motor level of C3 and above, and 45 patients have a motor level of C4. Respiratory information is insufficient on two of the C4 patients for them to be included in most of our analysis, but these two patients are included in the calculation of our mortality rates. Patients with C4 motor levels are further subdivided into a group of patients who were admitted to TIRR with an initial vital capacity below 1000 cc (26 patients) and a group of patients who were admitted with an initial vital capacity above 1000 cc (19 patients).

TABLE I
Texas Institute for Rehabilitation and Research
Respiratory Study 1959-1977

Age at onset 4 to 70 years (Av. = 22.7 years) of 59 male and eight female tetraplegics	
C3 and above	20
C4: Initial v.c. below 1000 cc	26
C4: Initial v.c. above 1000 cc	19
C4: Respiratory data insufficient	2
Total	67

v.c. = vital capacity.

A study of the aetiologies of these 67 spinal cord injuries reveals that 21 patients were injured in automobile accidents, 12 in football accidents, 12 by diving, nine by falls, five were hit by falling objects, four by gunshot wounds, two by other types of sports accidents, and two by miscellaneous causes. These aetiologies of injuries differ from that of our total spinal cord injury population in that in the latter group the patients who were injured by falls or hit by falling objects rank second in number to those injured by automobile accidents. These aetiologies are followed in order by gunshot wounds, diving accidents, and football and other sports accidents.

C3 and Above Tetraplegics

The 20 patients in this group of C3 and above tetraplegics were apneic on admission to TIRR. Their average age at onset of injury was 17.3 years with an age range of 4 to 33 years. All of these patients required tracheostomies, and the initial vital capacity was zero or less than 100 cc. Six of these 20 patients had a drop in the motor level to the point that they regained some spontaneous respiration. The maximum vital capacity of these six patients averaged 1180 cc and ranged from 800 cc to 2000 cc.

C4 Tetraplegics—Initial Vital Capacity below 1000 cc

This group includes a total of 26 patients, the majority of whom were admitted to TIRR within the first 3 weeks post-injury. Their average vital capacity on admission was 670 cc. The average maximum vital capacity attained was 1837 cc which represents an average gain of 1167 cc per patient. The average interval from initial to maximum vital capacity was 75.5 days. These patients who receive adequate pulmonary and rehabilitation therapy early after injury can usually attain a vital capacity which is capable of supporting their breathing without mechanical assistance. Even patients who are admitted to a rehabilitation centre several months post-onset may be capable of significant improvement in their vital capacity. One patient in this group of C4 tetraplegics was admitted 4 months post-injury with an initial vital capacity of 750 cc; he was able to attain a maximum vital capacity of over 2100 cc in a 46-day period. Sixteen of these 26 patients, or 61.5 per cent, required tracheostomies. The duration between performance and removal of the tracheostomies averaged 163.8 days.

C4 Tetraplegics—Initial Vital Capacity above 1000 cc

This group of C4 tetraplegics who were admitted to TIRR with an initial vital capacity above 1000 cc is composed of 19 patients, most of whom were admitted to TIRR within 60 days of their injury. The initial vital capacity was 1550 cc with an average maximum vital capacity of 2672 cc after appropriate therapy. This reflects an average gain in vital capacity of 1122 cc which was attained in an average time interval of 57 days. Two patients who were admitted to TIRR, one 6 months and one 8 months post-injury, had vital capacities of 1700 cc and 1200 cc, respectively. Even at these late admission dates, the vital capacities were increased to a maximum of 2600 cc and 2750 cc over the same average time interval of 2 months. Eight patients in this group of C4 tetraplegics had tracheostomies (42 per cent). The tracheostomies remained open an average of 46 days prior to their being removed.

All of the C4 tetraplegics, those patients who were admitted with this motor level with an average vital capacity below and above 1000 cc, totalled 45. Their average initial vital capacity was 1041 cc with a maximum vital capacity averaging 2190 cc which was attained in an average interval of 68 days. The average gain in vital capacity per patient was 1149 cc. In this overall group, 24 patients or 53 per cent had tracheostomies which remained open an average of 125 days.

Discharge Status

The discharge status following the first comprehensive rehabilitation admission reveals that of the 20 patients with injury C3 and above, six patients died, 12 patients were discharged with mechanical ventilation including five patients with phrenic stimulators, and two patients required no ventilatory equipment (Table II). The six patients (33 per cent) died in an average of 3 months post-injury while in TIRR. One of the two patients who was discharged without requiring mechanical respiratory support had a unilateral phrenic stimulator implanted prior to admission to TIRR which was unnecessary for his ventilation. Five patients had bilateral phrenic stimulators implanted, and at the time of discharge, these patients were on a progressive program of increasing phrenic stimulation and diminishing the other mechanical ventilation necessary.

Of the group of 28 patients with C4 tetraplegia who were admitted with an initial vital capacity of less than 1000 cc, two patients died, three were discharged

TABLE II
Discharge status

Tetraplegics	Dead	With equipment for respiration	EPR	No equipment
C3 and above (20)	6	12 (Inc. EPR)	5	2
C4 v.c. < 1000 cc (28)	2	3	0	23
C4 v.c. > 1000 cc (19)	1	0	0	18
Totals 67	9	15	5	43

with respiratory equipment, and 23 required no respiratory equipment. In the group of 19 C4 tetraplegics who were admitted to TIRR with an initial vital capacity greater than 1000 cc, one patient died, none of the patients required EPR or respiratory equipment, and 18 were discharged without any respiratory or ventilatory equipment necessary. In summary, the discharge status of the 67 patients reveals that nine patients died, 15 (including five EPR) required respiratory equipment, and 43 required no respiratory equipment whatsoever.

Mortality Rates

The three groups of patients discussed are each divided into two equal 7-year periods for comparison (Table III). The first 7-year period is 1963 through 1969, and the second period is 1970 through 1977. The first C4 and above patient who qualified for this study was admitted to TIRR in 1963. In the C3 and above tetraplegics, one patient is living, and three are dead from the first period. Eight are living, and eight are dead from the period 1970 through 1977. In the C4 tetraplegics who were admitted to TIRR with an initial vital capacity below 1000 cc, five patients are living, and three are dead from the first period, and 17 are living and three dead from the second time period. In the C4 tetraplegics who were

TABLE III
Mortality

	1963-1969		1970-1977	
	Living	Dead	Living	Dead
C3 and above	1	3	8	8
C4: v.c. below 1000 cc	5	3	17	3
C4: v.c. above 1000 cc	3	0	15	1
	<u>9</u>	<u>6</u>	<u>40</u>	<u>12</u>
Total	15		52	
Mortality %	40%		23%	
67 patients with 18 dead = 27% (1/2 post-discharge)				
Adjusted for lost to follow-up (5 patients) = 34%				

admitted with an initial vital capacity above 1000 cc, three patients are living and none dead from the 1963 through 1969 period, and 15 are living with one dead from the second time period. This results in an overall total of nine patients living and six dead in the 15 patients who were admitted to TIRR from 1963 through 1969. The mortality percentage of these tetraplegics is 40 per cent. In the period of 1970 through 1977, 40 patients are living, and 12 are dead. This results in a total of 52 patients with a mortality rate of 23 per cent. When the two groups are added together, of the total of 67 patients, 18 died with a mortality rate of 27 per cent. One half of these deaths occurred in the hospital, and the remainder of these patients died after being discharged from the rehabilitation programme. Five patients in this study were lost to follow-up, and if one assumes that these patients have died, then the mortality rate for the total number of 67 patients would be adjusted to 34 per cent.

Causes of Death

The major cause of death of these tetraplegic patients involves the cardio-respiratory system (six patients) with pneumonia, atelectasis, and hypoxia being major factors. Tracheal haemorrhage was the major terminating event in three patients. Two patients died a renal death, two of pulmonary embolus, one of meningitis due to an infected stab wound of the neck, and two died with intestinal obstruction and perforation with peritonitis. The causes of death in two patients are unknown. The duration of onset of injury to death of the nine patients who died in TIRR averaged 3 months; of the nine patients who died after discharge from the hospital, the average duration was 16 months.

TABLE IV

Survival curve (adjusted for loss to follow-up) based on 615 traumatic spinal cord lesion patients admitted to the Texas Institute for Rehabilitation and Research 1966-75 (closing date 31 December 1974)

The survival curve of 615 spinal cord patients injured who were admitted to TIRR between 1966 and 1975 when compared to a standard matched group for age and sex reveals a very rapid drop from the norm within the first 3 years (Rossi, 1977) (Table IV). After that, a curve parallels the normal survival rate. This curve indicates approximately 98 per cent survival after 1 year, 95 per cent after 2 years, and 93 per cent after 3 years post-injury. These survival curves are fairly similar for males and females with slightly less survival time for females by six to seven years post-onset. In survival curves based on our two groups of traumatic

TABLE V
Survival curves based on two groups of SCI's: C4 and above

spinal cord injuries C4 and above, the initial group of 16 patients who were admitted in 1963 through 1969 and the 51 patients who were admitted between 1970 through 1977, only 60 per cent survived the first year in the initial group while in the latter group, 85 per cent survived the first year (Table V). By the third year after admission, in the initial group, 55 per cent survived, and the curve then plateaus. In the group seen in 1970 through 1977, 80 per cent of the patients were surviving at the end of 3 years post-onset, and then this curve plateaus.

Conclusion

This is a study of 67 complete tetraplegic patients with motor levels of C4 and above from a patient population of 1468 patients with traumatic spinal cord injuries who were admitted to TIRR between 1959 and 1977. Mortality rates are compared in two successive 7-year periods according to the level of lesion. The mortality rate in the C3 and above tetraplegics has improved to approximately 50 per cent. The advent of electrophrenic respiration gives additional hope to those apnoic

patients who are highly motivated and who have a good family support system. Improved respiratory equipment and increased experience in respiratory support has enabled us to keep patients alive until spontaneous respirations return. This occurred in six of our 20 apnoic patients. Documented improvement in vital capacity was obtained in all C4 tetraplegics where vital capacity was initially above or below 1000 cc. The average gain in each group was over 1100 cc, and this type of improvement was able to be attained in several patients with late admission dates post-onset. Approximately half of this group had tracheostomies which were maintained on an average of 4 months. Mortality curves in two 7-year periods are parallel, but in the latter time period, the survival times are 25 per cent higher at the end of 1 year and 3 years.

Cardio-pulmonary deaths rank highest among the causes of death in patients with high spinal cord injuries. Improvement in respiratory machinery, techniques, and experience has allowed us to reduce the mortality rates considerably over the past 14 years. Improvement in the vital capacity can occur in all tetraplegics with diaphragmatic intervention to a point where home respiratory equipment for maintenance of respiration is rarely required.

RÉSUMÉ

Des 1468 malades ayant une lésion de la moëlle épinière due à un trauma qui ont été admis au Texas Institute for Rehabilitation and Research (TIRR) entre 1959 et 1977, 67 étaient tétraplégiques complets avec une lésion à C4 ou au-dessus. Une analyse est faite suivant l'âge, le sexe, le niveau de la lésion, l'origine de la lésion ainsi que la capacité vitale initiale et finale de ces malades. Un gain substantiel est obtenu pour la capacité vitale dans tous les tétraplégiques à C4 quelle que soit la capacité initiale. Vingt malades avec une lésion au niveau de C3 ou au-dessus ont été hospitalisés à TIRR depuis 1963. Cinq de ces 20 tétraplégiques ont eu un stimulateur phrénique bilatéral implanté. Les ratios de mortalité et les causes de mort sont présentées. Les courbes de survie sont détaillées pour 615 malades ayant une lésion due à un trauma comparées à un groupe normal avec caractéristiques semblables. Courbes de survie sont présentées également pour les deux groupes de tétraplégiques admis à TIRR entre 1963 et 1969 et entre 1970 et 1977.

ZUSAMMENFASSUNG

Von 1468 Patienten die zwischen 1959 und 1977 mit traumatischen Rückenmarkverletzungen in das Texas Institute for Rehabilitation and Research aufgenommen wurden, waren 67 total tetraplegisch mit motorischen Ausfällen in Bereich C4 und höher. Alter, Geschlecht, Art der Lähmung, Ätiologie der Verletzung und anfängliche und endgültige Vitalkapazität dieser Patienten werden analysiert. Bei allen C4 Gelähmten wurde unabhängig vom Ausgangsstatus eine beträchtliche Zunahme der Vitalkapazität erreicht. Seit 1963 sind zwanzig Patienten mit motorischen Ausfällen in Bereich C3 und höher in das TIRR aufgenommen worden. In fünf dieser Patienten wurden doppelseitige Zwerchfellstimulatoren implantiert. Sterblichkeit und Todesursachen dieser Patientengruppen werden beschrieben. Überlebenskurven von 615 Patienten mit traumatischen Rückenmarkverletzungen werden der einer Standardgruppe entgegengestellt. Dargestellt sind auch die Überlebenskurven für zwei Gruppen von hochtetraplegischen Patienten, die von 1963 bis 1969 bzw. 1970 bis 1977 in das TIRR aufgenommen worden sind.

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