A COMPARISON OF FOUR BEDS IN THE PREVENTION OF TISSUE ISCHAEMIA IN PARAPLEGIC PATIENTS

A PRELIMINARY REPORT

By M. CARPENDALE, M.D.¹

*Department of Plastic Surgery and Rehabilitation, Stanford University,
Children's Hospital at Stanford, Palo Alto, California*

INTRODUCTION

A TWO-HOURLY turning programme for paralytic patients is known to be effective in the prevention of bedsores. But this is disturbing to the patient's rest, arduous for the attendant and costly in attendant time.

The frequency of occurrence of bedsores suggests that although such a programme is feasible in a well-staffed hospital or nursing home it is difficult for a family at home and almost impossible for a patient living alone.

Yet it is known that low-density foam, air-water mattresses, and rocking beds all can reduce the amount of routine patient turning up to 10 hours without producing bedsores or any irreversible tissue ischaemia.

The importance or practical significance of this, is that to eliminate the routine 2-hourly turning programme through the night would reduce the amount of professional man hours necessary for adequate care and at the same time improve the patient's rest. It would also significantly reduce the cost of caring for such patients, and enable many patients at present incarcerated in nursing homes to return home.

The purpose of this study was to determine which of these beds produces least tissue ischaemia, and is the most comfortable, practical, and economical for the paralytic patient at home.

METHOD

Patients under treatment at the Paraplegic Units at the Santa Clara Valley Medical Center² were tested on each of four beds to determine the maximum time that they could lie in one position without producing a critical level of tissue ischaemia or sufficient discomfort that they wished to be turned.

Subjects. Seven well-nourished paraplegic and tetraplegic patients with partial or complete motor and sensory loss (Table I) volunteered to be subjects in this study.

Beds. Four types of beds were used.

1. *Standard Hospital Bed Frame and Standard Hospital Mattress.* Mattress—standard hospital 4-inch foam covered with plasticised cover and conventional cotton sheet lying on flat metal base on standard hospital bed.

¹ Present address: Dept. of Rehabilitation Medicine, V.A. Hospital, Martinez, California 94533.

² San José California.

2. *Low Density foam Mattresses on Standard Bed Frame.* The mattress consists of three layers of foam: Top Layer—1-inch 10 p.p.i. *reticulated* foam (Scottfoam);¹ Middle Layer—4-inch No. 2115 Low Density foam;¹ Bottom Layer—1-inch High Density foam.¹ All these layers held together and covered by special knitted combed cotton fitted sheet.

Mattress placed on standard bed with flat metal base.

3. *Air-water Mattress on Standard Bed Frame.* This consists of a special air mattress² placed on a standard 4-inch foam mattress covered with knit combed cotton fitted sheet on a standard bed frame with flat metal base. The air mattress was filled with sufficient water and about a litre of air to produce complete floatation of the patient so that he did not 'bottom out' under any bony prominence.

TABLE I
Patients in study of effect of different beds on tissue ischaemia

No.	Initials	Sex	Age	Diagnosis	Disability	Level of lesion	Complete or incomplete	Months since onset
1	D. G.	M	19	Sp. C. inj. fract C5-6	Tetra	C6	Complete	4
2	R. A.	M	28	Sp. C. inj. fract T7-8	Para	T8	Complete	2
3	M. G.	F	14	A-V malform	Para	T10	Incomplete	2
4	P. W.	F	24	Syringomyelia	Tetra	C6	Incomplete	12
5	W. B.	M	48	Herniated cervical disc	Tetra	C5	Incomplete	7
6	A. B.	F	16	Sp. C. inj. G.S.W.	Para	T10	Complete	20
7	K. K.	M	20	Sp. C. l	Tetra	C5	Complete	7

4. *Slow Rocking Bed.* The mattress consists of one layer of 4 inches of standard firm foam covered with a knitted combed cotton fitted sheet. This mattress lay on a flat metal base bed frame which oscillated in a head to toe to head direction around a central axis in the middle of the bed. It rocks 10° head down and 15° foot down and takes 10 minutes to complete the entire cycle.

Standard Protective Devices for All Patients. All patients on each bed wore 'Stryker' egg carton foam boots, and lay on artificial sheepskin.

Procedure. Each patient was nursed on each bed for 7 days, for a total of 28 days. All routine medical, nursing and rehabilitation programmes were continued as usual with the exception of the use of the bed and the special turning programme.

Special Turning Programme. The turning programme used was identical for each bed. The patient was initially positioned in the position of maximum

¹ Wilshire Chemicals, 15324 South Broadway, Gardena, California.

² Ted Williams—Air Mattress—Sears Roebuck Company.

comfort, usually between 10 and 11 p.m. At the appropriate time interval he was turned for inspection of skin and pressure points. If there was no evidence of tissue ischaemia or discomfort the patient was repositioned in the original position. If there was evidence of ischaemia or if the patient expressed any significant degree of discomfort in the original position, then he was turned, repositioned, and recorded as a turn because of ischaemia or discomfort.

Increasing Turning Interval (Table II). If the patient had no evidence of ischaemia or discomfort after being inspected and repositioned in the same position every 2 hours at the end of 8 hours, *i.e.* overnight, then the next night after normal daily activities, the time interval for inspection or repositioning was increased by $1\frac{1}{4}$ hours and this time interval was then increased by a further $1\frac{1}{4}$ hours daily up to 8 hours as long as the patient had no complaints and there was no evidence of adverse effects such as tissue ischaemia. The maximum time interval between inspections which produced no evidence of tissue ischaemia (flushing time < 5 seconds) or patient discomfort (up to a maximum of 8 hours) was recorded for each patient for each type of bed.

TABLE II

Programme for increasing time interval for inspection—repositioning of patients

	Time interval (hours) between each inspection repositioning of patients		
	Interval (hours)	Inspection times	No. of inspections
Day 1	2	1.30—5.30	4
Day 2	$3\frac{1}{4}$	2.15—5.30	2
Day 3	$4\frac{1}{2}$	3.30	1
Day 4	$5\frac{3}{4}$	4.45	1
Day 5	7	6.00	1
Day 6	8	7.00	1

Recording and Scoring for Discomfort, Erythema and Flushing Time.

A separate record was kept for each patient every night. On this was recorded the patient's name, type of bed, date, inspection time, the position, the erythema and flushing time over pressure points, and any special annotations (Table III). The scoring was done as follows.

Inspections. Each test interval and inspection that was evaluated was scored one point.

Discomfort. Each time the patient called the attendant to be turned or repositioned because of discomfort (exclusive of routine turns for inspection) scored one point. Therefore, a perfect score with no discomfort = 0.

Erythema and Flushing Scores. *Erythema Points.* The number of routine inspections at which any erythema was present over a given pressure point scored one point. Perfect score = 0

Flushing Time. At time of inspection, any erythema over a pressure point was compressed by the thumb for 5 seconds with a force sufficient to blanch the area. On quickly removing the compressing thumb the time (in seconds) for the blood to return to the blanched area to produce the same degree of erythema as the surrounding area was the score for that pressure point.

If the flushing time exceeded 5 seconds, the patient was discontinued from the study.

TABLE III

Sample recording and scoring of individual patient's erythema and flushing response

Patient—R. A.				Bed—standard		
				Flushing time (seconds)		
Date	Inspection time	Position	Sacrum or hip	Heels		
				L	R	
25/4/73	0 11.00 p.m.	Supine	0	0	0	
26/4/73	1 1.00 a.m.	Supine	0	1	1	
26/4/73	2 3.00 a.m.	Supine	0	1	1	
26/4/73	3 5.00 a.m.	Supine	1	1	1	
26/4/73	4 7.00 a.m.	Supine	1	1	2	
Score						
Total inspections = 4						
Total erythema points			2	4	4	
Total flushing points			2	4	5	
Average no. of points/inspection						
Average erythema points			0.5	1	1	
Average flushing points			0.5	1	1.25	

The average number of points for each interval was calculated by dividing the total number of erythema or flushing points by the number of inspections (Table III).

The average number of patient's erythema, flushing and discomfort points was then calculated for all patients for each turning interval on each bed (Table IV).

RESULTS

Nine patients were involved in the study but only seven patients were placed on all beds. Two patients were discharged prior to completion of the study.

The results of this study therefore relate to the seven patients who completed the programme (Table I).

Three patients (Nos. 3, 4 and 6) had to be turned because of discomfort and therefore are not included in the ischaemia test results. Three patients

(Nos. 1, 2 and 5) did not have to be turned at any time because of discomfort and therefore constitute the substance of the ischaemia test results.

One patient (No. 6) did not request to be turned for discomfort on any bed, but was noticed on a number of occasions to have altered her own position and therefore was not considered suitable to include in the group of ischaemia test results. This patient only on one occasion out of 20 nights showed evidence of

TABLE IV

Sample recording and scoring of group of patients' erythema, flushing and discomfort response

Bed—standard		Turning interval—2 hours				
No.	Patient initials	Flushing time (seconds)			Number of turns for	
		Sacrum or GT troch.	Heels or Malleoli		Inspection	Discomfort
			L	R		
1	D. G.	3	4	4	4	—
2	R. A.	2	4	5	4	—
3	M. G.	—	—	—	—	5
4	P. W.	—	—	—	—	4
5	W. B.	1	3	3	3	—
6	A. B.	—	—	—	—	4
7	K. K.	—	—	—	—	3
<i>Score—total PT</i>						
Total patients = 7					11	
Total inspections = 14						
Total erythema points = 6			11	11		
Total flushing = 6			11	12		
<i>Average no. of points</i>						
Average erythema points = 0.5			1	1		
Average flushing points = 0.5			1	1		

reactive hyperaemia. This was the one occasion when she chose to lie prone and the hyperaemia was evident after 2 hours on the dorsum of her foot.

Turns Related to Discomfort. The three patients who requested to be turned because of discomfort averaged three turns per night (range 2-6). There was no difference in the number of turns required to relieve discomfort on any of the four beds (Tables V and VI). And there was no difference on the nights when the patients were inspected every 2 hours or only once in 8 hours. Although this provides no objective evidence to indicate that one type of bed relieves discomfort better than another, subjectively patients all had definite preferences,

usually for the water mattress or the soft foam. The slow rocking bed in this study was small, narrow and had no gatch mechanism for sitting, and no over-bed

TABLE V

Number of patient turns/night for discomfort

Standard bed

Hours	Total	Average
2	8	4
3 $\frac{1}{4}$	5	2.5
4 $\frac{1}{2}$	6	3
5 $\frac{3}{4}$	7	3.5
7	3	3
8	3	3
Total for six intervals		32
Average for six intervals		19

Soft foam mattress

2	11	3.75
3 $\frac{1}{4}$	10	3.33
4 $\frac{1}{2}$	6	3
5 $\frac{3}{4}$	8	2.66
7	9	3
8	11	3.75
Total for six intervals		55
Total of average for six intervals		19

Water mattress

2	7	3.5
3 $\frac{1}{4}$	11	2.75
4 $\frac{1}{2}$	13	3.25
5 $\frac{3}{4}$	3	3
7	6	2
8	7	3.5
Total for six intervals		47
Total of average for six intervals		18

Rocking bed

2	9	4.5
3 $\frac{1}{4}$	10	2.5
4 $\frac{1}{2}$	10	3.3
5 $\frac{3}{4}$	9	3.0
7	5	2.5
8	8	4.0
Total for six intervals		51
Total of average for six intervals		18

bar and for these reasons did not compare favourably with the other beds. However, it appears that the slow rocking bed is less popular than the fast rocking

bed from the patient's point of view, and this is probably also more beneficial from a physiological view point.

TABLE VI

Summary of number of turns/night for discomfort on four beds

	Number of patient turns/night	
	Total for six intervals	Sum of average for six intervals
Standard bed	32	19
Soft foam mattress	55	19
Water mattress	47	18
Rocking bed	51	18

TABLE VII

Average scores of erythema and flushing points for three patients—for six different turning intervals on a standard bed

Standard bed						
Hours	Erythema points			Flushing time		
	Sacrum	Heels		Sacrum	Heels	
		L	R		L	R
2	0.5	I	I	0.5	I	I
3 $\frac{1}{4}$	0.5	I	I	0.7	I	I.1
4 $\frac{1}{2}$	0.3	I	I	0.3	I.3	I.3
5 $\frac{3}{4}$	0.3	I	I	0.7	I	I
7	0.3	I	0.6	0.3	I	I
8	0.5	I	I	0.5	2.0	2.5
Total	2.4	6	6.6	3.0	7.3	7.9
Average of six turning intervals						
	0.4	I	I.1	0.5	I.2	I.3

Tissue Ischaemia. No evidence of tissue ischaemia beyond the stage of reactive hyperaemia was seen on any patient on any bed for any of the turning intervals.

Average scores for erythema and flushing points for three patients on the standard bed show no difference between the shortest (2-hour) and longest (8-hour) interval (Table VII).

A comparison of the average scores for erythema and flushing points for these patients when the scores for the six turning intervals are averaged for each bed reveal no difference between any of the beds (Table VIII). A comparison of the average scores of erythema and flushing points for three patients on each of

TABLE VIII

Comparison of four beds by average scores for erythema and flushing points for three patients for six turning intervals

Bed	Erythema points			Flushing time		
	Sacrum	Heels		Sacrum	Heels	
		L	R		L	R
Standard	0.4	1	1.1	0.5	1.2	1.3
Foam	0.3	1	1.1	0.3	1.6	1.2
Water	0.2	1	1	0.3	1.1	1.6
Rocking	0.2	1	1	0.2	1.1	1.0

TABLE IX

Average scores of erythema and flushing points for three patients on four beds

2-hour test	Erythema points			Flushing time		
	Sacrum	Heels		Sacrum	Heels	
		L	R		L	R
Standard bed	0.5	1	1	0.5	1	1
Foam bed	0.4	1	1	0.4	1.4	1.3
Water bed	0	1	1	0	1.1	1.6
Rocking bed	0	1	1	0.4	1.1	1.1
Total	1.3	4	4	1.3	4.6	5.0
Average of four beds	0.3	1	1	0.3	1.1	1.2

the four test beds shows no difference whether the turning interval is every 2 hours (Table IX) or only once in 7 hours (Table X).

A comparison of the average scores for erythema and flushing points from three patients when summated for all beds for each turning interval shows no difference between turning intervals (Table XI).

Patients' and Staff's Preference for Beds. *Patients rated the beds as follows.* *Comfort.* 1. Water mattress and soft foam. 2. Standard bed. 3. Rocking bed.

Convenience for Transfer and Dressing. 1. Standard. 2. Rocking bed. 3. Soft foam. 4. Water mattress.

Staff rated the beds as follows. *Convenience for Positioning and Nursing Care.* 1. Standard bed. 2. Soft foam. 3. Water bed. 4. Rocking bed.

Physiologically Beneficial to Patients. 1. Rocking bed. 2. Water bed. 3. Soft foam. 4. Standard bed.

TABLE X

Average scores of erythema and flushing points for three patients on four beds

7-hour test	Erythema points			Flushing time		
	Heels			Heels		
	Sacrum	L	R	Sacrum	L	R
Standard bed	0.3	1	0.6	0.3	1	1
Foam bed	0	1	1	0	1.3	1
Water bed	0.3	1	1	0.3	1	1.7
Rocking bed	0.5	1	1	0.5	1	1
Total	1.1	4	3.6	1.1	4.3	4.7
Average of four beds	0.3	1	0.9	0.3	1.1	1.2

TABLE XI

Comparison of average scores for erythema and flushing points for three patients in four beds for each test interval

Hours	Erythema points			Flushing time		
	Heels			Heels		
	Sacrum	L	R	Sacrum	L	R
2	0.3	1	1	0.3	1.1	1.2
3 $\frac{1}{4}$	0.4	1	1	0.3	1	1
4 $\frac{1}{2}$	0.1	1	1	0.1	1.2	1.1
5 $\frac{3}{4}$	0.1	1	1	0.2	1.1	1.1
7	0.3	1	0.9	0.3	1.1	1.2

DISCUSSION

It had been anticipated that the number of turns because of discomfort might increase as the turning interval increased for all patients.

It is of interest to note that discomfort necessitated turning for half of the patients in this study and they required the same number of turns whether they were being inspected every 2 hours or once in 8 hours. Two of the patients (Nos. 3 and 4) were incomplete lesions and both appeared to have discomfort at rest. The third patient (No. 7) was a complete lesion, but appeared to be less well nourished than the other patients. Tissue ischaemia was no problem in any of these patients because discomfort necessitated turning before the tissues were compromised.

The three patients that went through increasing periods of tissue ischaemia clearly showed that when the patient wears Stryker boots and lies on a sheepskin in a supine position, that even on the standard bed there is no evidence of residual tissue ischaemia (*e.g.* increased flushing time or unblanching hyperaemia) even after 8 hours in one position. It seems important that the same study should be undertaken without the benefit of Stryker boots and artificial sheepskin, which is probably the way in which many patients would be nursed outside of special centres.

It is also apparent that under the circumstances of the present study the flushing test is not sensitive enough to measure small differences in tissue ischaemia.

It is also important to consider that even though three patients did each spend 8 hours without turning on four different beds that these were not on consecutive nights and that cumulative factors in tissue damage may occur which will finally lead to arteriolar thrombosis and ulceration. To test this, Patient I was for 7 weeks placed on a standard bed with a once nightly inspection, and turned after a $4\frac{1}{2}$ -hour interval without moving. He showed no evidence of any tissue ischaemia, and in fact a small abrasion in the natal cleft healed on this regime. Patient II was also placed on a similar programme for 3 weeks, and a 6-hourly interval for 1 week. Again no evidence of ischaemia was present and both patients much preferred this regime from the point of increased undisturbed sleep.

Although these findings suggest that the majority of well-nourished spinal injured patients wearing Stryker boots and lying on a sheepskin may be able to go 8 hours without turning, and show no evidence of tissue ischaemia, one cannot be sure that other evidence of stasis (*e.g.* phlebothrombosis, osteoporosis and atelectasis) may not occur although no evidence of these conditions was seen in any of the patients under study.

However, the benefit of increased undisturbed sleep for the patient and his family are important considerations and all the patients in the study requested to be kept on extended turning times because they found it preferable to the usual 2-hourly routine.

SUMMARY AND CONCLUSION

Seven paraplegic and tetraplegic patients were each evaluated on four different beds (standard, water mattress, soft foam, rocking bed) to determine optimum turning intervals for least tissue ischaemia and maximum comfort. The results of the present study indicate that:

1. Three paraplegic and tetraplegic patients wearing Stryker boots and lying on sheepskin showed no objective evidence of tissue ischaemia after remaining 8 hours in one position on a standard hospital bed.

2. The degree of ischaemia appears no different whether the patient is lying 2 or 8 hours unturned. It also appears to be no different whether the patient is turned on a standard bed, a soft foam mattress, a water mattress or a rocking bed.
3. Discomfort was the main cause for requesting to be turned in three of the seven patients in this study.
4. There was no difference in the amount of turning needed to relieve discomfort in any of the four test beds.
5. Patients most preferred the water and soft foam mattress beds.

Discussion

DR. L. MICHAELIS (*G.B.*). The regular turnings 2-hourly, 3-hourly for the first 4 or even 8 weeks, are certainly not a 'sacred cow' as you implied, but an absolute necessity and no bed, however expensive, will avoid this. What does a paper of seven cases of whom not all are traumatic or complete paraplegics prove? I think you are confusing the issue, but the funny thing is that the 'sacred cow' isn't even there because all the patients, long before they are discharged, stopped being turned every 2 or 3 hours and some altogether. They are sleeping, particularly complete cervical lesions, for 4 hours at a time and we let them sleep through without turning them or letting them turn themselves. When at home they continue this scheme. Those who develop sores at home do it through carelessness, knocking themselves and do not watch bruises, or have such a severe spasticity that friction might produce a sore.

PROFESSOR ASCOLI (*Italy*). Perhaps some of you will remember that 4 or 5 years ago I read a paper here on the subject of the turning system for the prevention of pressure sores. Really, there is no absolute rule, every patient is different from another. There are patients who cannot lie in prone position. What is really important is that the dangerous areas, particularly the sacral area, do not get in contact with any hard surface. You can keep a patient in supine position for the whole day but the patient should be on the Stryker or Foster turning frame.

CHAIRMAN (DR. CHESHIRE (*U.S.A.*)). Our problem with turning was the hypotensive patient and the maintenance of renal filtration pressure. For this reason we used the basic Mark I Guttman sorbo-rubber pack bed, on top of which we used the alternating pressure air mattress. The critical moment is to decide when it was necessary to turn the patient for reason of skin pressure and this problem was particularly critical in patients who had not only a spinal cord injury but also multiple injuries with massive haemorrhages, ruptured spleen and so on.

SIR LUDWIG GUTTMANN (*G.B.*). I do not wish to be cynical, but Dr. Carpendale's suggestion that Stoke Mandeville should carry out similar investigations as he has reported here, comes a little late in the day. Almost 30 years ago the 'sacred cow' as Dr. Carpendale calls the systematic 2-hourly turning on pillow packs and later on foam rubber packs, was introduced at Stoke Mandeville for the prevention of sores in the acute and early stages of paraplegia and tetraplegia, following research with the then available hospital beds including the Hey-Groves turning bed. The position of the patient on the packs was such that the bony parts—*i.e.* sacrum, trochanters and heels were always placed between the packs so that not the slightest pressure occurred. These packs proved a breakthrough in those years in the management of traumatic cord lesions and, in particular, in the preventing and healing of pressure sores. The bony parts in the paralysed area are particularly sensitive to ischaemia due to the reduced resistance of the tissues to pressure as the result of the interruption of the vasomotor control following spinal cord injury. Once vasomotor control returned—and for this purpose the regular turning as an exercise was of great importance—as Dr. Michaelis rightly pointed out,

the 2-hourly turning was replaced by 3-hourly, 4-hourly turning, etc. and the patient was taught before discharge to adopt the turning which was necessary in his individual case. However, an equally important point in preventing pressure sores is to avoid recumbency in the acute and early stages which, as is well known, results in stagnation of urine in the urinary tract producing ascending infection and stone formation. Dr. Cheshire rightly pointed out that the maintenance of renal filtration pressure is of utmost importance in these early stages. It is true that to turn the patient manually needs great effort on the part of the nursing staff, and that is the reason why electrically controlled turning beds such as the Stoke Mandeville/Egerton or the Keane Rotorest have been introduced, which facilitate the nursing tremendously. As Michaelis already mentioned, the seven cases examined by Dr. Carpendale with the various beds have been several months after the acute stages and, moreover, three of them were incomplete lesions. Therefore, I do not feel that Dr. Carpendale proved his point at all.

DR. CARPENDALE (*U.S.A.*). I am not trying to say that we should start off on another thing. What I was saying was that, maybe, we should review our programme to start everybody off with 2 hours and, instead of waiting until the day before they go home or ask for leave, extending the time of turning or reviewing it, maybe right early on, or maybe we should start conditioning them for longer and longer periods.