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Contract Number DAMD17-97-C-7006

TITLE: Cervical Spinal Motion During Orotacheal Intubation

PRINCIPAL INVESTIGATOR: Vincent C. Traynelis, M.D.

CONTRACTING ORGANIZATION: University of Iowa
Iowa City, Iowa 52242

REPORT DATE: January 1999

TYPE OF REPORT: Annual

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for public release;
distribution unlimited

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
January 1999

3. REPORT TYPE AND DATES COVERED
Annual (31 Dec 97 - 30 Dec 98)

4. TITLE AND SUBTITLE
Cervical Spinal Motion During Orotacheal Intubation

5. FUNDING NUMBERS
DAMD17-97-C-7006

6. AUTHOR(S)
Vincent C. Traynelis, M.D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of Iowa
Iowa City, Iowa 52242

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

19990301003

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200*

Ten fresh human cadavers were intubated while recording cervical motion using a cinefluoroscopic technique. Segmental cervical motion from the occiput through C5 was measured in both the intact spine and following the creation of a C4-5 posterior-ligamentous injury in all cadavers. Each intubation was performed using no external stabilization, Gardner-Wells traction and manual in-line cervical immobilization. In a completely destabilized C4-5 segment, traction effectively eliminates subluxation, but results in increased distraction. Immobilization effectively eliminates distraction, but results in increased subluxation. Application of no traction or immobilization has intermediate results with more subluxation than traction, and less restriction of longitudinal motion than immobilization. Nine patients without significant cervical pathology and normal motion of flexion/extension views underwent fluoroscopic monitoring during intubation without and with traction. The traction was applied by hand using Gardner-Wells tongs. One patient could not be intubated safely while traction was administered. Traction during intubation decreases motion of all cervical segments in live patients, with the C2-C3 and C4-C5 levels most affected.

14. SUBJECT TERMS
spinal injury, intubation, spinal cord injury, spinal immobilization

15. NUMBER OF PAGES
21

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

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N. C. Braynelis 1/28/99

PI - Signature   Date

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INTRODUCTION

The goal of emergency airway management in patients with suspected cervical injuries is to secure the airway as quickly as possible without worsening the patient's neurologic condition. Current Advanced Trauma Life Support guidelines recommend orotracheal intubation with manual in-line cervical immobilization, although nasotracheal intubation may be considered in the spontaneously breathing patient depending on the skill of the caregiver.[1] There is conflicting evidence whether blind nasotracheal intubation reduces cervical motion[2,6,7,9], and it is less reliable and more time-consuming than the orotracheal approach.[5,10,16,17] This technique is also associated with a substantial incidence of complications, including epistaxis, vomiting, aspiration, and retropharyngeal laceration,[5,8,10,23] and is best performed in cooperative patients.

The data documenting the efficacy of any method in reducing cervical movement during intubation are limited. Most published studies focus on movement of the intact spine, but very little work has been done on motion of the unstable cervical spine during intubation.[15] Although a few reports have focused on the motion of a single unstable level[3,6,7] no previous investigation has quantified segmental motion during intubation of the injured cervical spine and the effect of commonly used stabilization procedures on that motion.

Our group has previously demonstrated that in living patients with intact cervical spines the majority of motion occurs at the craniovertebral junction, followed by the atlantoaxial junction, with only a minor contribution from the subaxial spine.[20] Our early work did not address the effects of stabilization or instability on cervical motion during intubation. Given the minimal contribution of the subaxial cervical spine to the motion of intubation in the normal condition, the question arises as to what effect increased subaxial instability has on overall motion and how do stabilization maneuvers limit this motion.

BODY

We had proposed testing our hypotheses by performing 6 specific projects, two in each year of the study. In the 1998-99 year we examined cervical motion during orotracheal intubation in cadavers without and with traction, immobilization, and a hard cervical collar. Although we had anticipated studying only 6 cadavers, we were able to obtain data from 10. Cervical motion was evaluated during orotracheal intubation in cadavers before and after creation of a significant posterior ligamentous disruption. We also evaluated cervical motion during orotracheal intubation in patients without and with cervical traction. To date we have studied nine patients. The details of both of these studies follow.

CADAVER STUDY

Experimental Methods

Ten fresh human cadaveric were used for this study. All subjects had intact cervical spines and were evaluated under fluoroscopy and found to have a normal range of motion prior to intubation. Each subject was placed supine on a flat surface and a routine direct laryngoscopy and orotracheal intubation was performed in all cases using a #3 Macintosh blade and a wire-reinforced endotracheal tube. Exposure of the glottis was limited to that necessary to allow passage of the endotracheal tube through the vocal cords under direct visualization. The same procedure was used for each method of stabilization in the intact as well as the posterior ligament-disrupted subjects. Minimal visualization was intentional to produce minimal cervical movement as would be done in a trauma situation. All intubations were performed by an experienced faculty anesthesiologist.

Procedure

Each subject was intubated serially while applying no external stabilization, manual in-line cervical immobilization then traction. A neurosurgeon performed all stabilization maneuvers for all intubations. For traction, Gardner-Wells tongs were placed and force was exerted throughout the intubation procedure by hand until the neurosurgeon felt that it was a proper amount based on clinical experience. Force was measured with a spring-gauge scale and ranged from 7-10 pounds. For in-line cervical immobilization, the head was manually stabilized by grasping the mastoid processes bilaterally to limit movement throughout the intubation sequence without application of traction.

After completion of the intact cervical intubation series, each subject was placed in a prone position and a midline cervical incision was made. The C4-5 level was identified with fluoroscopy and the supraspinous, interspinous, facet ligaments, posterior longitudinal ligament and ligamentum flavum were incised with a scalpel blade. An osteotome was then used to cut the anterior and posterior annulus, disc and the anterior longitudinal ligament. The facets were bilaterally dislocated following the ligamentous disruption and then repostioned in the normal alignment. The wound was closed following destabilization. The subject was returned to the supine position. Dynamic fluoroscopic examination verified a complete segmental injury and a high degree of instability. The previously describe sequence of intubations was repeated.

In all cases, the entire laryngoscopy and intubation sequence was monitored and recorded with continuous lateral fluoroscopy of the cervical spine. The occipital base through C5 was visualized and the head maintained contact with the table at all times throughout the sequence. Cervical segments caudal to C5 could not be consistently visualized due to the shoulders. Fluoroscopic images were recorded on a VHS-formatted video recorder interfaced with the fluoroscopy machine.

Data Processing

Video images were digitized using a frame grabber, either IP Lab Spectrum version 2.3.1e (Signal Analysis, Vienna, Virginia) or Flashpoint version 4.0 (Integral Technologies, Indianapolis, Indiana). The digitized 640x480 grayscale images were analyzed using freely available image analysis software. On a Macintosh computer, NIH Image 1.55 or 1.61 was used (The National Institutes of Health, Bethesda, MD available over the internet by anonymous FTP from ftp://zippy.nimh.nih.gov/pub/nih-image). On a PC-compatible, UTHSCSA ImageTool 1.27 was used (developed at the University of Texas Health Science Center at San Antonio, Texas and available over the internet by anonymous FTP from ftp://maxrad6.uthscsa.edu).

Each intubation sequence was digitized at five distinct stages: (1) **Baseline** denoted by the head and neck in neutral position prior to any manipulation or insertion of the laryngoscope, (2) **L1** at first appearance of the laryngoscope in the glottis, (3) **L2** after the laryngoscope was advanced into the vallecula and a ventral lifting force was applied to its maximal excursion prior to passage of the endotracheal tube, (4) **Tube** when the endotracheal tube passed through the vocal cords, and (5) **Post** after the laryngoscope was removed and the head and neck came to their final resting positions.

Two reproducible bony reference points were chosen for each segment that remained constant for that intubation sequence. The line created by intersecting each set of reference points was then referenced to either the horizon or vertical, depending on its absolute position in space, such that forward rotation of the segment would increase the angular measurement and backward rotation would decrease the angular measurement. The horizontal/vertical line remained constant during that intubation sequence. Reproducibility with this technique is very good as previously published[20] with an average intraobserver variability of 0.37° and an average interobserver variability of 0.48°

Results

A detailed analysis of antero-posterior (AP) subluxation and distraction at the level of injury has been performed.

The median distraction for each stage of intubation for no traction, traction, and immobilization are depicted in Figure 1. No increase in distraction occurred throughout the standard intubation sequence. It is interesting to note that following a standard intubation (post phase) there was less distraction than before the sequence began (baseline). Immobilization effectively prevented distraction from occurring at all phases of intubation including the post intubation period. Distraction did occur with the application of traction. This was most severe during the tube phase of intubation. The median distraction at this point was over 1.6 mm.

Figure 2 shows a comparison of the maximum distractions resulting from intubation while applying no traction, traction and immobilization. Application of no traction during intubation resulted in reduced distraction whereas application of traction resulted in a median distraction of 1.1 mm. Immobilization resulted in a median distraction of 0 mm. The data were assessed using the nonparametric Wilcoxon signed-rank test. Maximum Distraction was significantly increased during intubation under traction as compared to intubation without traction ($p = 0.03$).

The median subluxation for each stage of intubation for no traction, traction, and immobilization are depicted in Figure 3. Both intubation without traction and while immobilizing the cadavers head resulted in anterolisthesis of C4 on C5 which was maximal during the tube phase. The median anterolisthesis during the tube phase with immobilization was 1.9 mm compared to 1.0 mm with no traction and 0 mm with traction. This anterolisthesis reduced to baseline in the post phase with no traction, but not with immobilization. Traction effectively prevented subluxation from occurring at all phases of intubation including the post intubation period.

Figure 4 shows a comparison of the maximum subluxations resulting from intubation while applying no traction, traction and immobilization. Application of no traction during intubation resulted in a median anterior subluxation of C4 on C5 of 1.0 mm whereas immobilization resulted in a median subluxation of 1.9 mm. Traction resulted in a median distraction of 0 mm.

Discussion

In summary, this work demonstrates the strengths and weaknesses of the most popular methods of cervical spine stabilization during intubation. In a completely destabilized C4-5 segment, traction effectively eliminates subluxation, but results in increased distraction. Immobilization effectively eliminates distraction, but results in increased subluxation. Application of no traction or immobilization has intermediate results with more subluxation than traction, and less restriction of longitudinal motion than immobilization (although the motion that occurs is a reduction in the space between C4 and C5).

PATIENT STUDY

Experimental Methods

Nine human subjects were studied. The preoperative clinical exam included a detailed spinal history and examination. The demographics of these patients and the airway assessment are shown in Table 1. Although some patients were undergoing surgery for cervical disc disease, the upper cervical spine (occiput to axis) and the subaxial spine to C5 were clinically and radiographically normal. Motion in flexion and extension was radiographically within the normal range. The airway of each subject was assessed using the Malampati system.[19]

Each patient was given a general anesthetic and ventilation maintained with a mask. Gardner-Wells tongs were applied in the usual fashion. A standard intubation with a MacIntosh blade was performed without traction. Following this intubation the endotracheal tube was removed and ventilation was again achieved by masking. In-line traction was administered manually using Gardner-Wells tongs by the principal investigator. This was done by pulling on a spring gauge which was attached to the tongs. The amount of traction delivered was determined by the principal investigator and based entirely on clinical judgement. An observer noted the reading on the spring gauge which was consistently in the range of 10-12 pounds. The patient was intubated while the traction was applied. The ease of intubation was assessed by the anesthesiologist. The optimal airway view was scored according to Cormack.[4] The Malampati Grade, ease or difficulty of intubation, and Cormack scores for each patient are listed in Table 2.

All intubations were performed under continuous fluoroscopic monitoring. The fluoroscopic images were recorded on a VHS-formatted video recorder interfaced with the fluoroscopy machine and digitized as previously described. There was less than 1 mm of anteroposterior translation at each motion segment. The segmental angular motion was determined as previously described.

Results

The motion data are graphically displayed in Figures 5 and 6. The motion of the cervical spine during intubation without traction was similar to that described earlier in this report and in our previous publication.[20] Hand-held traction altered the motion characteristics of the cervical spine during intubation as compared to the freely mobile spine. Specifically, motion across the O-C1 segment decreased by about 2° at the L2 and Tube phases. Motion at the C1-C2 level during these phases decreased 4° and 3°, respectively. The greatest change occurred at the C2-C3 segment where almost no motion occurred throughout the entire intubation process. There was a slight decrease in motion at C3-C4 during the tube phase only. There was little motion detected at C4-C5 accounting for about a 2° difference in most phases of intubation as compared to the nontraction condition. Overall, the effect of traction on cervical spinal motion during intubation in live patients was almost identical to that noted in our cadaveric study.

A detailed report including statistical analysis of the data is being prepared for publication.

Discussion

The cervical motion of the non-traction subjects was similar to the motion we have previously reported. Traction decreased motion in all phases of intubation as compared to the non-traction condition. This decrease was greatest at the junction between the upper and lower cervical spine, C2-C3 and at the most caudal recorded level of the subaxial cervical spine (C4-C5). The data compare very favorably with the data from the above reported cadaver study.

We were unable to visualize the vocal cords well enough to safely intubate subject #3 while traction was being administered. The non-traction intubation was graded as easy. It is notable that although the Malampati grade of this individual was II. Subject #7 had a Malampati score of II and intubation during traction was moderately difficult. Subject #8 had a Malampati scoare of I but his neck was very short and thick. He was moderately difficult to mask and intubate. Traction did not alter the difficulty of intubation and the view of the larynx was improved with traction.

As mentioned previously, a detailed analysis and report for peer review publication is being prepared.

CONCLUSIONS

CONCLUSIONS FROM CADAVERIC STUDY

In summary, this work demonstrates the strengths and weaknesses of the most popular methods of cervical spine stabilization during intubation. In a completely destabilized C4-5 segment, traction effectively eliminates subluxation, but results in increased distraction. Immobilization effectively eliminates distraction, but results in increased subluxation. Application of no traction or immobilization has intermediate results with more subluxation than traction, and less restriction of longitudinal motion than immobilization (although the motion that occurs is a reduction in the space between C4 and C5).

Essentially, therefore, neither traction or and hel immobilization are ideal. Further analysis of angular rotation data is being performed at this time. Once that is complete, then a recommendation as to which method is superior may be made.

CONCLUSIONS FROM PATIENT STUDY

Accurate data was collected from nine patients. These data suggest that traction decreases motion in all cervical segments. The decrease affects the C2-C3 and C4-C5 levels the greatest. The Malampati grade may be able to predict difficulty in performing orotracheal intubations while traction is being administered. This may be useful in determining which patients may require an awake or fiberoptic intubation as compared to those which may be managed with traction alone. The next phase of the patient study will focus on the effect of immobilization in terms of spinal motion. Combining these data will improve our ability to safely manage patients with cervical instability.

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LEGENDS

Figure 1	Graph comparing median distraction at each stage of intubation for different methods of stabilization.
Figure 2	Bar graph comparing median maximum distraction at the injured C4-C5 segment during intubation for different methods of stabilization.
Figure 3	Graph comparing antero-posterior translation at each stage of intubation for different methods of stabilization.
Figure 4	Bar graph comparing the maximum antero-posterior translation for different methods of stabilization.
Figure 5	Graph comparing median values of motion experienced during each stage of non-traction patient intubation for levels O-C1 through C4-5. Positive numbers represent degrees of extension and negative numbers degrees of flexion.
Figure 6	Graph comparing median values of motion experienced during each stage of traction patient intubation for levels O-C1 through C4-5. Positive numbers represent degrees of extension and negative numbers degrees of flexion.
Table 1	Subject Demographics
Table 2	Malampati and Cormack scores for individual patients and specific events.

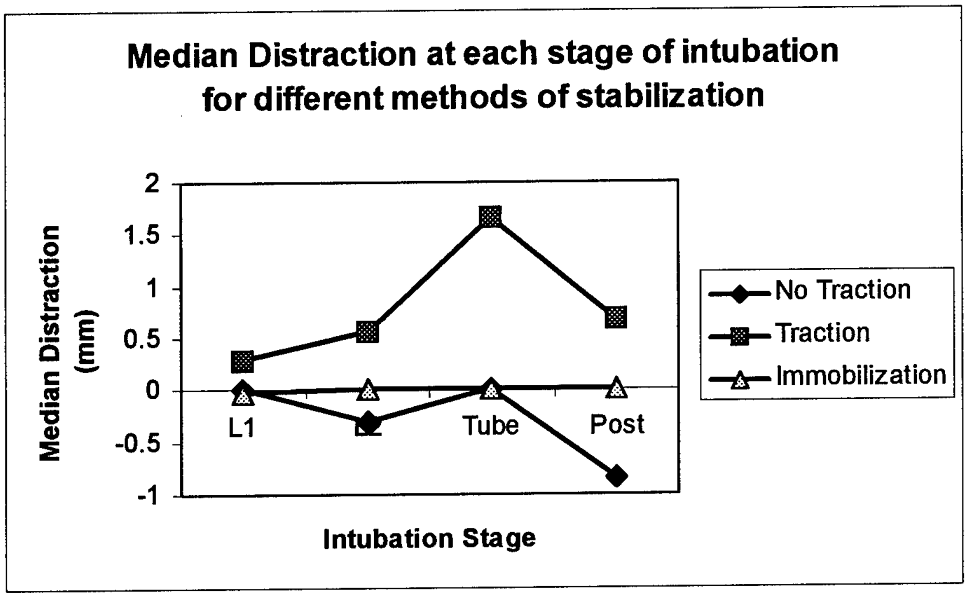
Median Distraction at each stage of intubation
for different methods of stabilization
Median Distraction
(mm)
2
1.5
1
0.5
0
-0.5
-1
L1
Tube
Post
Intubation Stage
No Traction
Traction
Immobilization

Figure 1

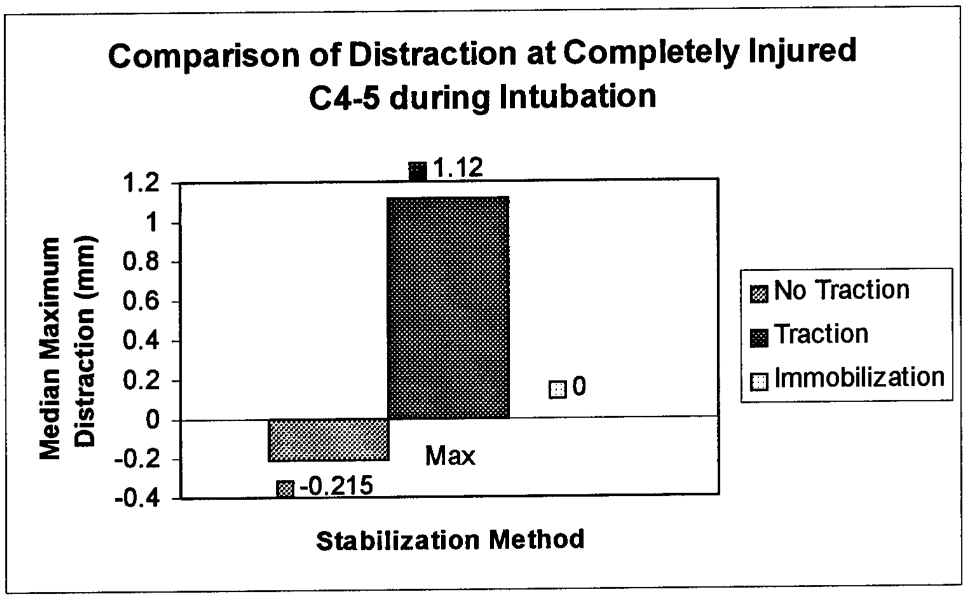
Comparison of Distraction at Completely Injured C4-5 during Intubation
Median Maximum Distraction (mm)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
1.12
0
-0.215
Max
Stabilization Method
No Traction
Traction
Immobilization

Figure 2

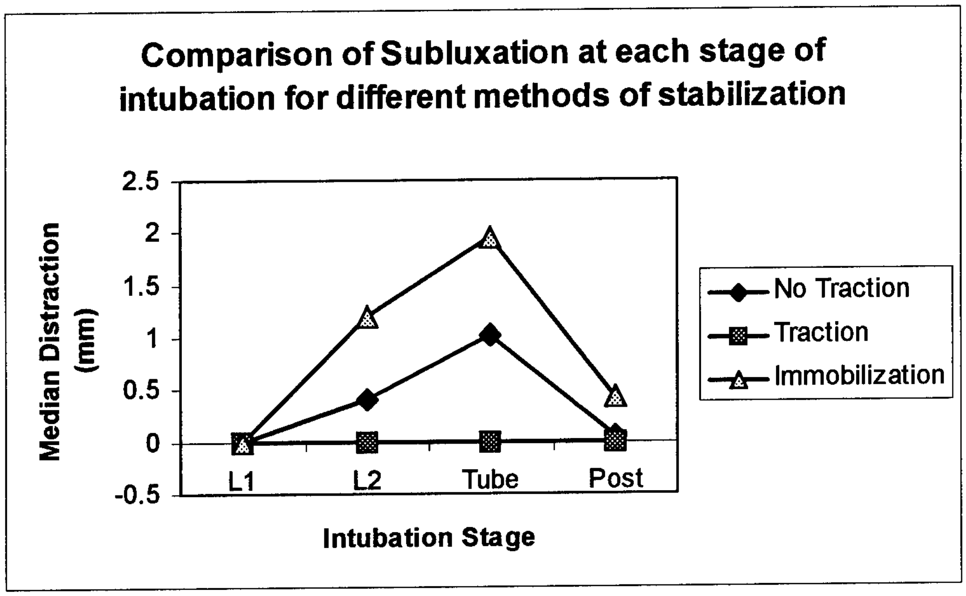
Comparison of Subluxation at each stage of intubation for different methods of stabilization
Median Distraction (mm)
2.5
2
1.5
1
0.5
0
-0.5
L1
L2
Tube
Post
Intubation Stage
No Traction
Traction
Immobilization

Figure 3

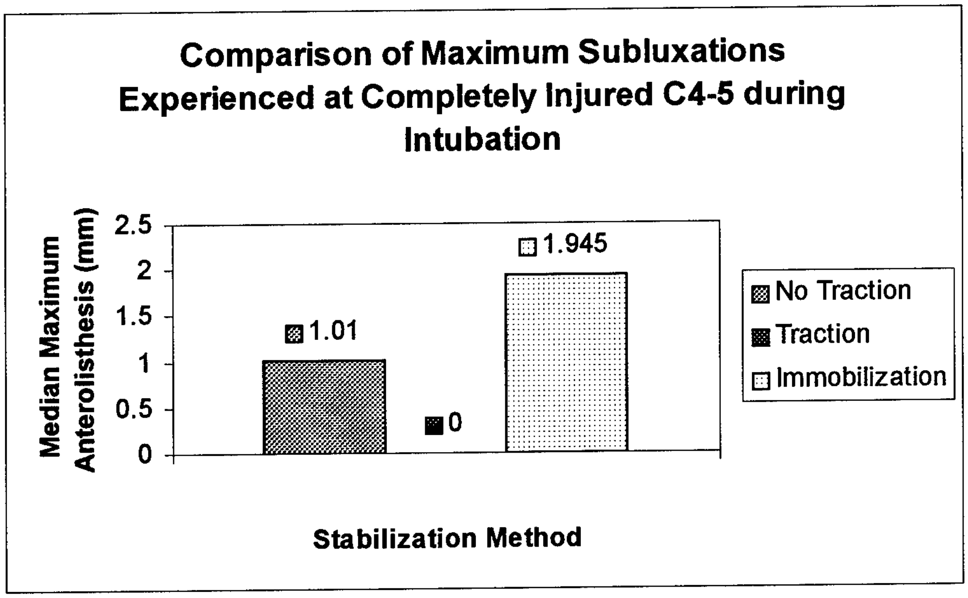
Comparison of Maximum Subluxations Experienced at Completely Injured C4-5 during Intubation
Median Maximum Anterolisthesis (mm)
2.5
2
1.5
1
0.5
0
1.01
0
1.945
No Traction
Traction
Immobilization
Stabilization Method

Figure 4

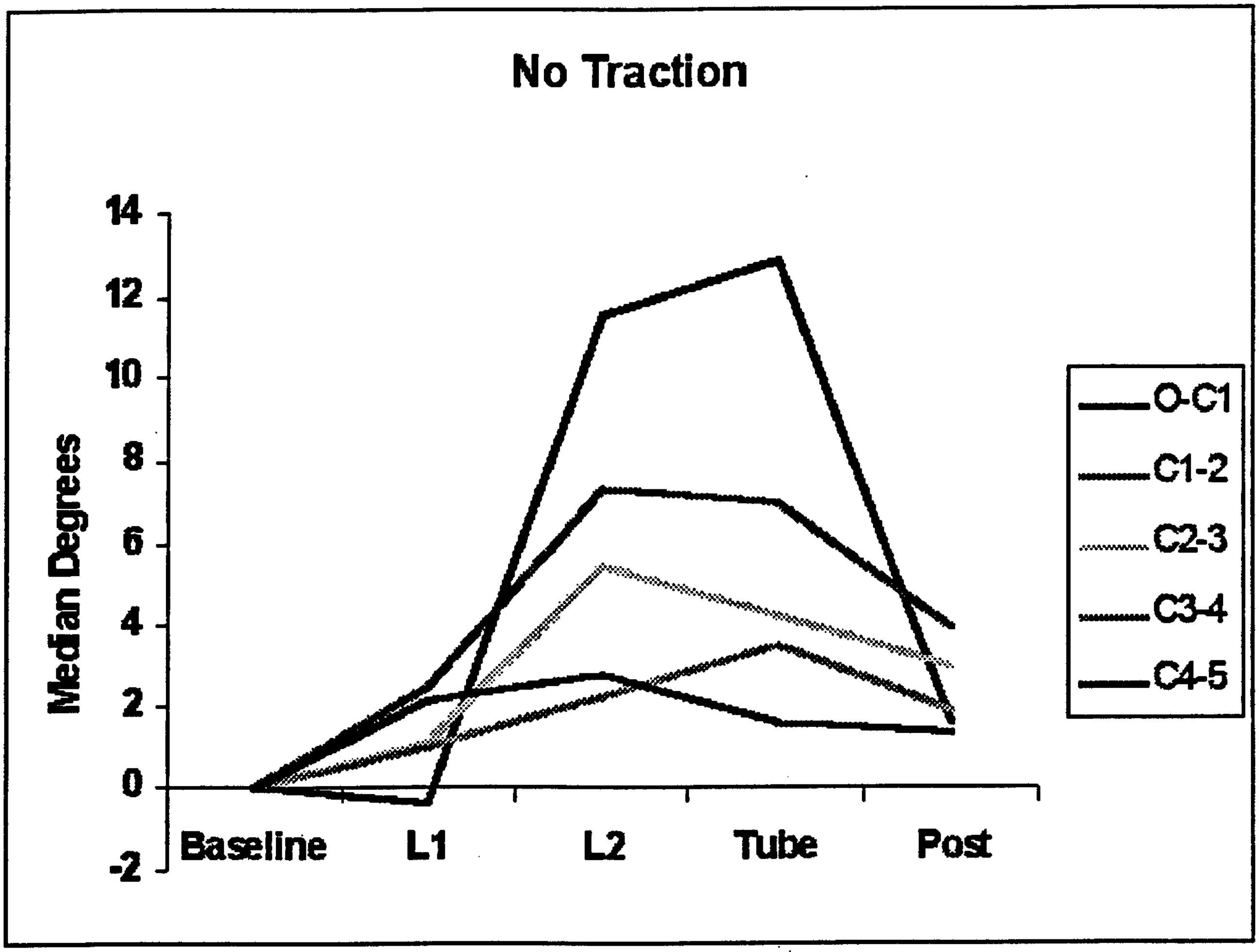
No Traction
14
12
10
8
6
4
2
0
-2
Median Degrees
Baseline
L1
L2
Tube
Post
O-C1
C1-2
C2-3
C3-4
C4-5

FIGURE 5

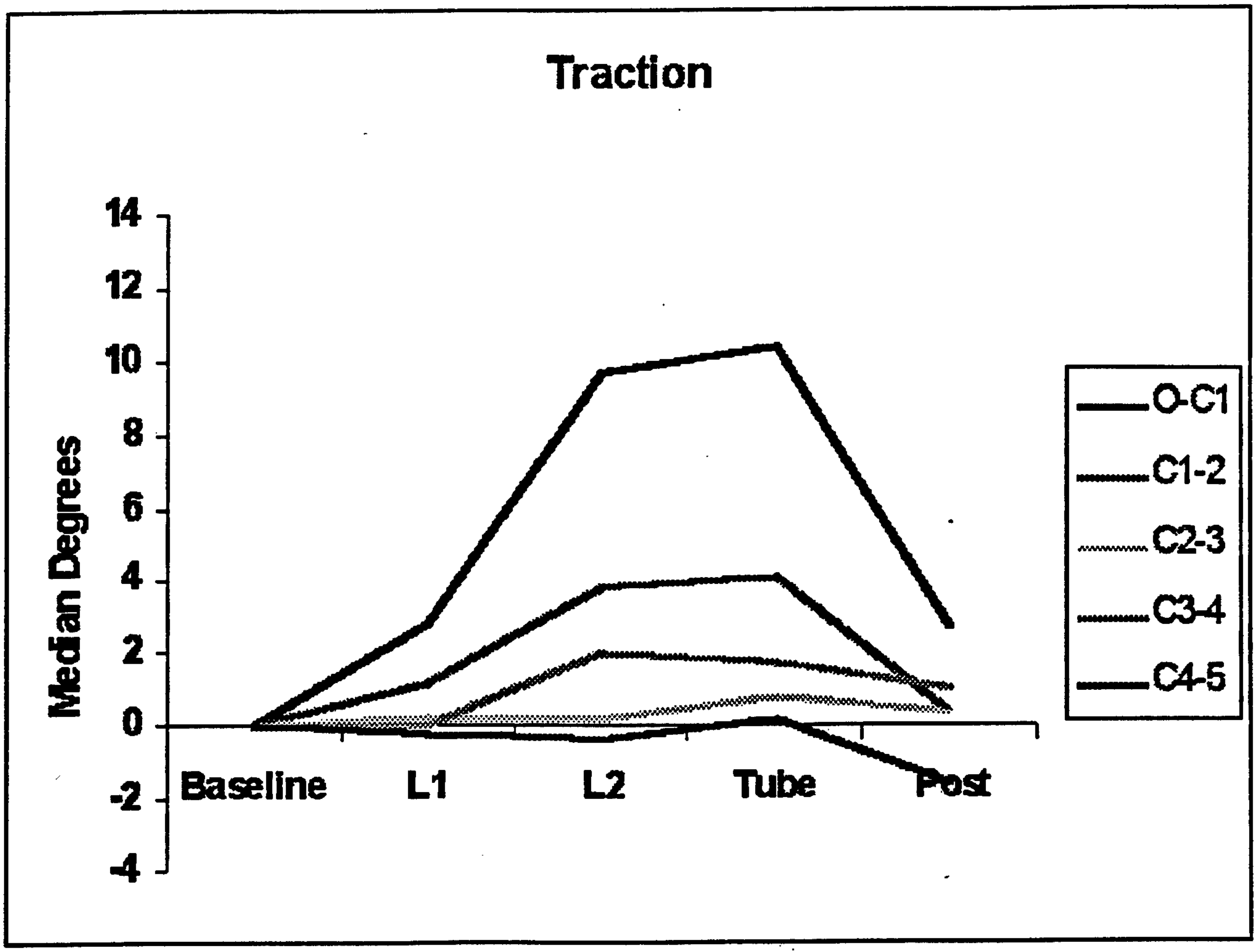
Traction
Median Degrees
14
12
10
8
6
4
2
0
-2
-4
Baseline
L1
L2
Tube
Post
O-C1
C1-2
C2-3
C3-4
C4-5

FIGURE 6

TABLE 1

Subject Number	Sex	Age (years)	Height (feet)	Weight (pounds)
1	Female	46	5.5	187
2	Male	59	5.7	185
3	Male	45	5.5	200
4	Male	50	5.8	285
5	Male	47	5.8	174
6	Male	74	5.5	140
7	Female	39	5.4	174
8	Male	55	5.8	185
9	Female	57	5.5	185

TABLE 2

Subject Number	Malampati	Mask Ventilation	1st Laryngoscopy, view (Cormack)	2nd Laryngoscopy, view (Cormack)
1	I	easy	easy, I	easy, II
2	I	easy	easy, II	easy, II
3	II	easy	easy, I	difficult, III
4	I	easy	easy, I	easy, I
5	I	easy	easy, II	easy, II
6	II	easy	easy, II	easy, II
7	II	easy	easy, II	moderate, III
8	I	moderate	moderate, III	moderate, II
9	II	easy	easy, II	easy, II