



Nonsurgical Care of Neurogenic Thoracic Outlet Syndrome in a National Collegiate Athletic Association Division 1 Athletic Conference

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Background: Thoracic outlet syndrome (TOS) is a disabling condition which may end an athletic career. While physical therapy (PT) is the initial treatment for TOS, there is a paucity of management outcomes data. Our goal is to report the outcome of nonsurgical care in a National Collegiate Athletic Association (NCAA) Division 1 athletic conference.

Methods: The prospectively maintained PAC12 Health Analytics Program Database was searched for athletes with TOS from 2016–2022. Athletes with neurogenic TOS (NTOS) diagnosis were identified. Outcomes of nonsurgical care were analyzed according to success of PT alone, need for specialty consultation and interventional procedures. Analysis compared nonsurgical and surgical management.

Results: Fifteen thousand six hundred nine athletes (6,874 men and 8,735 women) in 21 sports were registered. TOS was identified in 76 (0.48%) athletes: 69 (90.8%) NTOS. All 69 athletes with NTOS were initially managed with nonsurgical modalities. Ultimately, this failed in 9 (13%), who required surgery. Nonsurgical care included PT 69 (100%), subspecialty consultation in 48 (69%), and interventional procedures in 5 (7%). Of the 69 athletes with NTOS, 55 (79.7%) experienced complete resolution of symptoms and 14 (20%) noted partial resolution. PT alone was used to treat 21 athletes, 17 (81%) of these noted complete resolution of symptoms. Of the 48 who required specialty consultation complete resolution of symptoms was noted in 48 (79.2%). Interventional procedures were used to treat 5, and 3 (60%) noted complete symptom resolution. Of the 60 athletes managed with nonsurgical care complete resolution of symptoms was noted in 81.7%, whereas surgical decompression resulted in resolution of symptoms in 66.7% of athletes. All athletes returned to competition: 95% returned to unrestricted competition, and 5% with some restriction. This included 96.2% of NTOS managed without surgery and 85.7% of NTOS managed surgically.

Conclusion: This report details outcomes of nonsurgical care of TOS in a Division 1 NCAA Collegiate Conference based on a prospective, conference-wide database. The majority (84%) of athletes were managed with nonsurgical care. This was successful with resolution of symptoms in 93% and unrestricted return to competition in 96%. Nonsurgical care is successful and provides effective resolution of TOS symptoms for most elite collegiate athletes.

Conflicts of interest: The authors declare no conflicts of interest.

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INTRODUCTION

Compression of neurovascular structures at the thoracic outlet resulting in symptomatic presentation is the basis of thoracic outlet syndrome (TOS).¹ While uncommon, TOS is well recognized, and various treatment algorithms have been proposed. The vascular presentations of thoracic outlet syndrome (VTOS) tend to require prompt intervention. Unlike the vascular presentations, the neurogenic presentation of TOS (NTOS) is most often treated initially with nonsurgical approaches. Nonsurgical care of NTOS patients is widely recognized as appropriate in all but those presenting with functional deficits such as the Gilliatt-Sumner hand where denervation leading to muscle atrophy indicates an advanced condition.² Nonsurgical interventions are thought to be successful in many NTOS patients; however, success rates have ranged from 39–70%.^{3,4}

Athletes represent a unique subset of NTOS patients given their demographics, and mechanisms of injury. Their discipline, motivation, drive, and expectations are significantly different from the general population.⁵ For these reasons, outcomes of surgical interventions for NTOS in athletes have generated considerable interest. In contrast, the nonsurgical management of athletes with NTOS has not garnered similar attention. Most of the available information is the result of single-center experiences with limited detail as to nonsurgical care. This imposes a limited perspective as to the incidence, management, and outcome of NTOS in athletes.

Until recently, the PAC12 Conference was an association of collegiate (CO) athletic programs in the western United States, consisting of National Collegiate Athletic Association (NCAA) Division 1 teams. The NCAA organizes and regulates CO athletic competitions among 1,100 schools in the United States and Canada. The Division 1 teams are the elite of CO athletics. The leadership of PAC12 during the collection of the data made a commitment to “find ways to reduce injuries, share current best practices and latest studies, and conduct research to uncover new ways to keep student athletes as safe as possible.” As part of this commitment, the PAC12 Health Analytics Program (HAP) was formed. This group developed and maintained the HAP Database which focused on health-care informatics, research, and analysis. Our goal is to report findings of nonsurgical management of NTOS in PAC12 athletes based on data from the PAC12 health analytics database.⁶

METHODS

PAC12 Health Analytic Database

A formal research proposal was submitted to the PAC12 conference Health Analytic Database (PAC12HAD). Following peer review and confirmation of institutional review board (IRB) approval, access was granted to data focused on TOS from 2016 through 2022 recorded in the PAC12HAD. The PAC12HAD is a prospectively collected and continuously maintained database covering all athletes enrolled in PAC12 Conference schools. At the time covered by this report the PAC12 schools included teams from University of Arizona, Arizona State University, University of California, Berkeley, University of California, Los Angeles (UCLA), University of Colorado, Boulder, University of Oregon, Oregon State University, University of Southern California, Stanford University, University of Utah, University of Washington, and Washington State University. The database collects deidentified information on athletes competing in 21 sports. Database domains include age, gender, sport, and injury details. Care domains included use of physical therapy (PT), medication, testing, consultation, interventional procedures, and surgery. Outcome data included relief of symptoms, and return to competition (RTC) with or without restrictions. The database is limited in granularity such that information may indicate treatment with medication, but does not specify which medications may have been used.

Organization of Analysis

We have organized the data as best possible to conform with the SVS reporting standards. [1] Data regarding sports played, injury characteristics (frequency, relation to sports, type injury, onset) were abstracted for analysis. For purposes of this review, nonoperative care was stratified into 3 categories: (1) PT alone, (2) PT and subspecialty consultation, and (3) interventional procedures such as Botox injections. These are seen as a progression of care continuum with increased severity and persistence of symptoms leading to the next category of care. Surgery was reserved for cases not responding to noninvasive modalities. The primary endpoints of the analysis are resolution of symptoms and RTC. Analysis focused on only NTOS patients.

Statistical Analysis

Chi-square tests were used to assess the association between categorical variables. Fisher exact test was

Table I. PAC12 athletic roster 2016–2022

Sport	Athletes	NTOS	%	OR	CI	P value
Track and Field	1,631	4	0.3	reference	0	0
Football	3,341	6	0.2	0.73	0.17–3.53	0.74
Rowing	1,435	16	1.1	4.59	1.47–18.88	0.003 ^a
Soccer	1,108	0	0	-	-	-
Baseball	1,089	5	0.5	1.88	0.4–9.48	0.5
Basketball	919	2	0.2	0.89	0.08–6.2	1
Swimming	893	6	0.7	2.75	0.65–13.28	0.18
Unique Sports	680	1	0.2	0.6	0.01–6.07	1
Volleyball	580	5	0.9	3.54	0.76–17.87	0.06
Tennis	463	11	2.4	9.9	2.91–42.79	0.000032 ^a
Golf	461	0	0	-	-	-
Softball	454	6	1.3	5.45	1.28–26.32	0.01 ^a
Cross-Country	443	0	0	-	-	-
Water Polo	438	3	0.7	2.81	0.41–16.64	0.17
Lacrosse	414	0	0	-	-	-
Gymnastics	364	2	0.6	2.25	0.2–15.74	0.3
Beach Volleyball	287	1	0.4	1.42	0.03–14.44	0.56
Wrestling	232	1	0.4	1.76	0.04–17.88	0.49
Skiing	198	0	0	-	-	-
Diving	96	0	0	-	-	-
Field Hockey	83	0	0	-	-	-
Total	15,609	69	0.4			

CI, confidence interval; OR, odds ratio.

^aP value < 0.05.

used for analysis with small sample sizes. Odds ratios were calculated along with confidence interval and probability calculations. Statistical significance was established for probability values less than 0.05.

IRB Approval

The UCLA institutional review board review and approval was obtained prior to being granted access to the PAC12 data (IRB, protocol IRB#22–001804).

RESULTS

Between 2016 and 2022 15,609 athletes (6,874 men and 8,735 women) were registered in PAC12 teams. TOS was identified in 76 (0.48%) athletes: 69 (90.8%) NTOS and 7 (9.2%) VTOS. This report concerns care of the 69 athletes diagnosed with NTOS. These included 26 (37.7%) men and 43 (62.3%) women. The average age of the 69 athletes with NTOS was 19.8 years; for men the average age was 20.29 and for women 19.53 years.

Sports Affected

The PAC12 Analytic Database includes 21 sports: football, track and field, cross country track, rowing, soccer, baseball, basketball, swimming, unique sports, volleyball, tennis, golf, softball, water polo,

lacrosse, gymnastics, beach volleyball, wrestling, skiing, diving, and field hockey. The rate of developing NTOS ranged from 0% to 2.3%.

Athletes in 14 of the 21 NCAA sports teams developed NTOS: tennis, softball, rowing, volleyball, swimming, baseball, water polo, gymnastics, wrestling, beach volleyball, track and field, basketball, football, and unique sports. Within this group the chance of developing NTOS was not equally distributed. The odds ratios of developing TOS among athletes in these 14 sports range from 0.6 to 9.9 (Table I) with track and field used as the reference sport (Fig. 1).

Athletes in 8 sports were successfully managed with no-surgical care only. These include basketball, beach volleyball, football, gymnastics, track and field, unique sports, volleyball, and wrestling. Competitors in 7 sports ultimately required surgery for NTOS: Baseball, rowing, softball, swimming, tennis, and water polo. The percentage of athletes in these sports who required surgery is 40% of baseball players, 33% of water polo, 18% of rowers, 16% of softball, 16% of swimmers, and 9% of tennis players (Table II).

Injury Characteristics

Injuries were characterized according to the number of injuries an athlete suffered, the relation to sports,

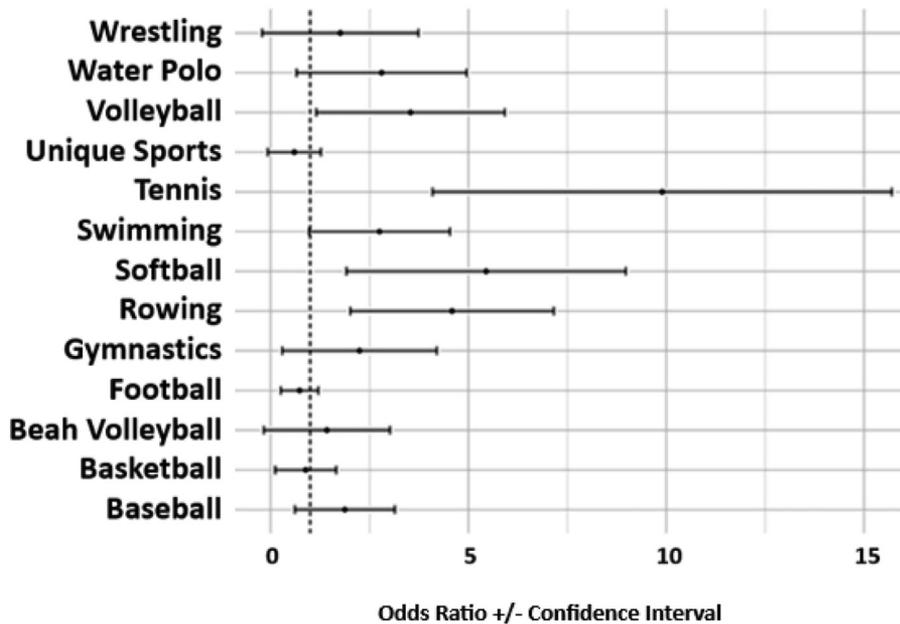


Fig. 1. Odds of neurogenic thoracic outlet syndrome by sport relative to track and field.

occurrence, and onset of symptoms. The average number of injuries was 1.0 ± 0.2 . The vast majority (78.3% were attributed to the sports played by the athlete. Most of these were new injuries (73%), however preexisting injuries were noted in 6.0%, a first recurrence was noted in 11.9% and multiple recurrences were noted in 9.0%. The onset of symptoms was acute in 50.7% and related to chronic overuse in 49.3% (Table III).

Management

All athletes with NTOS (69) were initially managed with PT. PT alone was sufficient to treat 21 (30.43%). PT and subspecialty consultation was required for 48 (69%). Procedural intervention was required for 5 (7.2%). Surgery was required for 9 (13%) who failed combined nonsurgical treatments.

Symptom Resolution

Overall complete symptom resolution was noted in 55 of 69 (79.75%). Persistent, milder symptoms were noted to persist in 14 (20.29%). Of the 21 patients managed with PT alone, complete symptom resolution was noted in 17 (80.9%). For 48 patients who required consultation with a specialist, complete resolution was noted in 79.1%. Interventional procedures were used to treat 5 patients, of which 3 (60%) had complete resolution of

symptoms. Overall, 60 of the 69 (86.9%) patients were managed with nonsurgical modalities. Of these, 49 (81.7%) experienced complete resolution of symptoms, and 11 (18.3%) had persistence of some symptoms. Surgery was required for 9 athletes, and 6 (66.7%) of these had complete resolution of symptoms, while 3 (33.3%) had persistence of symptoms (Table IV).

RTC

Data regarding RTC were conditioned by attrition of subjects. The distribution of impact on competition for nonoperative management of NTOS is displayed in Figure 2. Subjects were lost to analysis by reason of leaving campus prior to return to play and those lost to follow-up. These causes resulted in loss of 9 (13%) athletes; of which 2 (2.9%) graduated, and 7 (10%) were lost to follow-up, leaving 60 athletes for analysis. RTC data were available for 60 of the athletes that returned to competition. Of these, 57 (95%) returned to unrestricted competition, and 3 (5%) with some restriction on play. RTC data are available for 19 of the 21 athletes who were managed with PT alone. Of these 19 athletes, 18 (94.7%) returned to play without restriction and 1 (5.3%) returned with restrictions. RTC data are available for 41 of the 48 athletes who were managed with the help of consultant specialists. Of these 41 athletes, 39 (95.1%) returned to unrestricted competition and 2 (4.9%) returned with

Table II. Treatment received by sport

Sport	All affected	Nonoperative	%	Operative	%
Baseball	5	3	60	2	40
Basketball	2	2	100	-	-
Beach Volleyball	1	1	100	-	-
Football	6	6	100	-	-
Gymnastics	2	2	100	-	-
Rowing	16	13	81.25	3	18.75
Softball	6	5	83.3	1	16.6
Swimming	6	5	83.3	1	16.6
Tennis	11	10	90.91	1	9.09
Track and Field	4	4	100	-	-
Unique Sports	1	1	100	-	-
Volleyball	5	5	100	-	-
Water Polo	3	2	66.6	1	33.3
Wrestling	1	1	100	-	-
Total	69	60	86.9	9	13

Table III. NTOS injury characteristics

	All (<i>N</i> = 69)	Nonoperative (<i>N</i> = 60)	Operative (<i>N</i> = 9)	<i>P</i> value
Injuries (average \pm S.D.)	1.0 (\pm) 0.2	1	1.1 (\pm) 0.2	0.53
Sports Related (%)	78.3	77	87.5	0.5
Injury Type (%)				0.004
New Injury	73.1	78	37.5	-
Preexisting	6	6.8	0	-
First Recurrence	11.9	6.8	50	-
Multiple Recurrence	9	8.5	12.5	-
Symptom Onset (%)				
Acute	50.7	52.5	37.5	0.43
Chronic/Overuse	49.3	47.5	62.5	-

SD, standard deviation.

Table IV. Symptom resolution

	<i>N</i>	%	Yes	%	No	%	<i>P</i> value
All Patients	69	100	55	79.7	14	20.3	-
PT Only	21	30.4	17	81	4	19.1	1
PT & Consult	48	69.6	38	79.2	10	20.8	1
Procedure	5	7.2	3	60	2	40	0.23
All Nonoperative	60	87	49	81.7	11	18.3	0.42
Operative	9	13	6	66.7	3	33.3	0.42

N, number.

some restrictions. RTC data are available for 2 of the 5 patients managed with interventional procedures. Both were able to return to unrestricted competition. RTC data were available for 7 of the 9 athletes who underwent surgical decompression. Of these 7 athletes, 6 returned to unrestricted competition and 1 had some restriction but returned to the team (Table V).

Recurrence

Recurrent NTOS symptoms were noted in 4 athletes. All had been managed with nonsurgical modalities at the time of initial diagnosis and were able to RTC. After recurrence of TOS, all were initially managed with nonsurgical care. This was successful for 3, and 1 required surgery. After treatment for

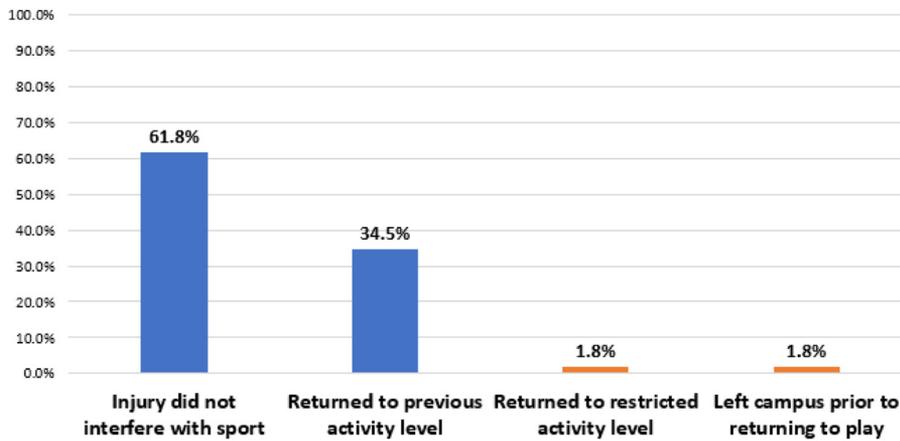


Fig. 2. Nonoperative neurogenic thoracic outlet syndrome performance outcomes.

Table V. Return to competition

	Overall	%	Unrestricted	%	Restricted	%	P value
All Patients	60	100	57	95	3	5	-
PT Only	19	31.7	18	94.7	1	5.3	0.54
Consult	41	68.3	39	95.1	2	4.9	0.54
Procedure	2	3.3	2	100	0	0	1
All Nonoperative	53	88.3	51	96.2	2	3.8	0.1
Operative	7	11.7	6	85.7	1	14.3	0.1

recurrent NTOS, all were able to return to play without symptoms.

DISCUSSION

Athletes represent a unique TOS patient population. While the number of athletes affected with NTOS is far smaller than the general population, the physical demands, and stresses inherent to athletic competition may place athletes at increased risk of NTOS. Literature regarding athletes with TOS initially focused on surgical outcomes of vascular complications.⁷⁻⁹ Other authors reported surgical outcomes of athletes with both NTOS and VTOS.¹⁰⁻¹⁵ While nonsurgical care is a widely accepted standard in management of NTOS in the general population, the role of nonsurgical care in athletes with NTOS has not been extensively reviewed.

Nonoperative management of NTOS involves several elements including PT, subspecialty evaluation, and injection-based treatment. Many reports have considered PT alone in management of NTOS and have indicated variable results.^{3,4,16-18} Raff observed relief of symptoms in 83 of 117 (70.9%)

patients with PT.⁴ Similarly, Peet noted 39 of 55 (70.9%) of his NTOS patients were improved with PT.¹⁶ Novak noted a slightly lower success rate where 25 of 42 (59%) patients reported improved symptoms.¹⁷ More recently, Balderman noted success of PT in 31% of NTOS patients.³

The role of subspecialty evaluation in the management of NTOS in elite athletes has not been assessed in prior reports. Our report is unique in noting the important role of subspecialists in assessing and treating NTOS. Specialty care involves accurately diagnosing and managing NTOS and is often provided by Vascular Surgeons. In the PAC12 Dataset, subspecialty consultation was required in 69.6% of all NTOS patients. This resulted in complete relief of symptoms in 79.2% and unrestricted RTC in 95% of athletes.

Interventional procedures in the management of NTOS principally involve chemodenervation of the scalene muscles and have become a significant element in nonsurgical care. This has been reported by several authors with varying degrees of success.¹⁹⁻²¹ The principal attraction of interventional procedures is the possibility of avoiding surgery; however, this treatment often requires repeat

interventions to maintain symptom relief. Jordan compared the effect of botulinum toxin chemodenervation to Lidocaine when injected into the scalene muscles and suggested that chemodenervation of the scalene muscles may be helpful in temporizing symptoms in patients with TOS awaiting definitive surgical decompression.¹⁹ In 2010 Christo published a prospective study of patients undergoing Botox injections for NTOS.²⁰ They found that patients experienced substantial relief from pain at 1, 2, and 3 months postinjection and concluded that “a single, computed tomography-guided Botox injection into the anterior scalene muscle may offer an effective, minimally invasive treatment for NTOS.” Torriani et al. reported their experience with Botox as treatment for NTOS in 2010. Out of 41 patients that underwent injections to both scalene and pectoralis minor muscles, 69% experienced symptom improvement, concluding that Botox is safe, well tolerated and provides satisfactory relief of symptoms.²¹

Reports of nonsurgical care of NTOS in elite athletes are rare. Focusing on elite athletes, Chandra presented the use of TOS-specific PT treatment algorithms as being predictive of operative success in symptom control prior to decompression.¹⁰ Of the 27 athletes initially treated with the Edgelow PT protocol 18 demonstrated improvement. Based on this improvement, they were selected for surgery, and following surgery 82% returned to competition. An alternative use of PT is illustrated by, Talutis et al. In a series of 36 adolescent athletes diagnosed with NTOS, PT was used as the first line of treatment in all.¹³ Failure of successful response to PT was considered an indication for further evaluation and possible surgery. Similarly, Olson reported a sequential approach to NTOS in athletes where PT is followed by chemodenervation (“BTI”). Surgery was reserved for those who failed PT and BTI.²² Using this approach, 36 elite athletes with NTOS were studied. PT was noted to be helpful in 83% and 44% required no further care. BTI was used to treat 56% of the athletes with 88% reporting improvement and after BTI, 35% required no further care. Out of the original cohort, 11 (32%) went on to require surgery.

Our report details a unique collection of information archived in the PAC12 HAD. The PAC12 dataset indicates a differential risk of developing NTOS among the 21 sports recorded. Odds ratios identify volleyball, tennis, rowing, and softball as sports at higher risk of developing NTOS compared to a reference group of track and field. Based on this dataset, 87% of athletes will be successfully treated with nonsurgical care. Of these, 82% experienced

complete resolution of symptoms and 96% were able to resume unrestricted athletic competition at the preinjury activity level.

The discrepancy between complete symptom resolution and RTC has been noted in prior publications.^{11,13,14,22} In a report of 36 adolescent athletes with NTOS, Talutis reported resolution of symptoms was observed in 27/36 (75%) and RTC was recorded in 30 of 36 (83.3%) cases.¹³ A second project compared success of surgery for NTOS in CO and high-school (HS) athletes. Resolution of symptoms was noted in 65% (HS) and 63% (CO). RTC was seen in 79% (HS) and 67% (CO).¹⁴ In the report by Olson, 88% of those who received chemodenervation were improved, and 58% returned to compete.²² In the PAC12 dataset, 82% of athletes treated with nonsurgical care experienced complete resolution of symptoms and 96% were able to return to unrestricted play.

LIMITATIONS

Our report is limited by the nature of information collected in the PAC12 HAD. While the data were recorded in a contemporaneous manner, the data fields lack the granularity which may be desired to further understand the role of subspecialist and diagnostic evaluations completed. The retrospective nature of the review may allow for post-hoc judgment and bias as to the significance of findings. Our ability to statistically analyze our data and come to significant conclusions is limited by the relatively small number of subjects.

CONCLUSIONS

This report details the outcome of nonsurgical care across a Division 1 NCAA Collegiate Conference based on a prospective, conference-wide database. The majority (87%) of athletes were successfully managed with nonsurgical care resulting in complete resolution of symptoms in 81% and unrestricted RTC for 96%. Nonsurgical care is highly successful and provides effective resolution of NTOS symptoms for most elite athletes.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Stephanie D. Talutis: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Jesus G. Ulloa:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Sharon L. Hame:** Writing –

review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Hugh A. Gelabert:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization.

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