Clinical and Photoplethysmographic Assessment of Thoracic Outlet Arterial Compression*

John Harris MS, FRACS, FRCS, FACS,** William Huang MB, BS,** Pauline Tyrer BSc(Hons),** Alison Burnett RN, RVT,** James May MS, FRACS, FACS**

ABSTRACT **This study was undertaken to determine the prevalence of upper extremity arterial compression and to compare clinical and photoplethysmographic (PPG) assessment of pulse obliteration in 145 asymptomatic individuals. There were 81 males and 64 females who were clinically well and in full employment. All were studied on a voluntary basis by one examiner. They included hospital staff (29), word processor operators (12), railway workers (43), computer programmers (32), panel beaters (5) and a miscellaneous group (24). Forty-six (32%) of the 145 individuals showed reproducible obliteration of their radial pulse with postural change. Bilateral compression was present in 17%. Arterial compression was most frequently provoked using a "stick up" position in which the forearms are elevated with the elbows held by the sides and the shoulders forced back. Adson's test was the least useful way to demonstrate arterial compression. There was no significant sex or occupational difference demonstrated. PPG was positive in 49 (34%) of 145 individuals. Twenty-two of these did not have pulse loss detected clinically. Twenty individuals, with clinical pulse obliteration, did not have a positive PPG. Arterial compression at the thoracic outlet can be provoked in over 30% of otherwise normal individuals. There is considerable overlap between clinical and PPG detection of arterial compression and the test should therefore be interpreted with caution.**

Introduction

Arterial complications from neurovascular compression at the thoracic outlet are rare although the relationship between cervical rib, subclavian aneurysm and thromboembolic phenomenon in the upper extremity has been known for many years.[1] Roos[2] draws a clear distinction between arterial compression noted incidentally in a normal population and symptomatic neurovascular compression associated with thoracic outlet syndromes. In an extensive clinical experience, almost 99% of patients with thoracic outlet syndrome had neurological symptoms mostly resulting from anomalous fibrous bands compressing the lower brachial plexus. The thoracic bony structure was usually normal.[2] Other authors, in smaller series, have reported a higher prevalence of arterial complications ranging from 5%[3] to over 20% in some European centers.[4,5] In these reports, arterial complications have usually occurred with some skeletal abnormality, most commonly the presence of a cervical rib, although arterial complications have been encountered in patients with a radiologically normal bony thorax.[4,5]

Permanent arterial damage has not been associated with positional arterial compression found incidentally in otherwise normal adults.[5] However, arterial damage may take many years to develop. Patients with arterial complications of thoracic outlet syndrome are usually older than those encountered with only neurological symptoms.[5] We are unaware of any long term study of positional arterial compression which would confirm its benign nature.

Photoplethysmography (PPG) has been recommended as a way to detect arterial compression.[6,7] PPG may be a useful way to screen for arterial compression as it is simpler to perform than other forms of upper extremity pulse detection.[8] This study was undertaken to determine the prevalence of upper extremity arterial compression in asymptomatic volunteers and to compare clinical and photoplethysmographic (PPG) detection of pulse obliteration.

Materials and Methods

The prevalence of arterial compression was determined in 145 asymptomatic individuals who were clinically well and in full employment. There were 81 males and 64 females with a mean age of 29 years (range 16 to 64 years). They included hospital staff (29), word processor operators (12), railway workers (43), computer programmers (32), panel beaters (5) and a miscellaneous group (24). Information was sought about each individual's age, sex, hand dominance and occupation.

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**Vascular Surgical Service, Royal Prince Alfred Hospital, University of Sydney

Address for correspondence: John Harris, Department of Surgery, Blackburn Building, University of Sydney, N.S.W. 2006 Australia

Blood pressure was recorded in both arms. Arterial compression was considered present if reproducible radial pulse obliteration was detected during the following postural changes: (1) Hyperabduction of the arms, with the shoulders in full external rotation, to 90° and then 180°. (2) A "stick up" position where the hands were held up with the elbows drawn into the sides and the shoulders forced posteriorly (Figure 1). (3) Standing in an exaggerated military posture with the shoulders drawn backward and downwards. (4) The Adson maneuver where the neck is extended with the head turned towards the side being tested.[9] Each individual was encouraged to make a maximal effort during each provocative maneuver.

The postural changes were repeated using photoplethysmography to detect pulse loss. Photopulse sensors were applied to the index fingers with transparent double-sided adhesive tape and then connected to a photopulse adaptor†. Recordings were made using a two channel recorder. The photoplethysmograph was calibrated with a photoplethysmographic reference standard.†† The PPG was considered positive only if there was complete loss of arterial pulsation.

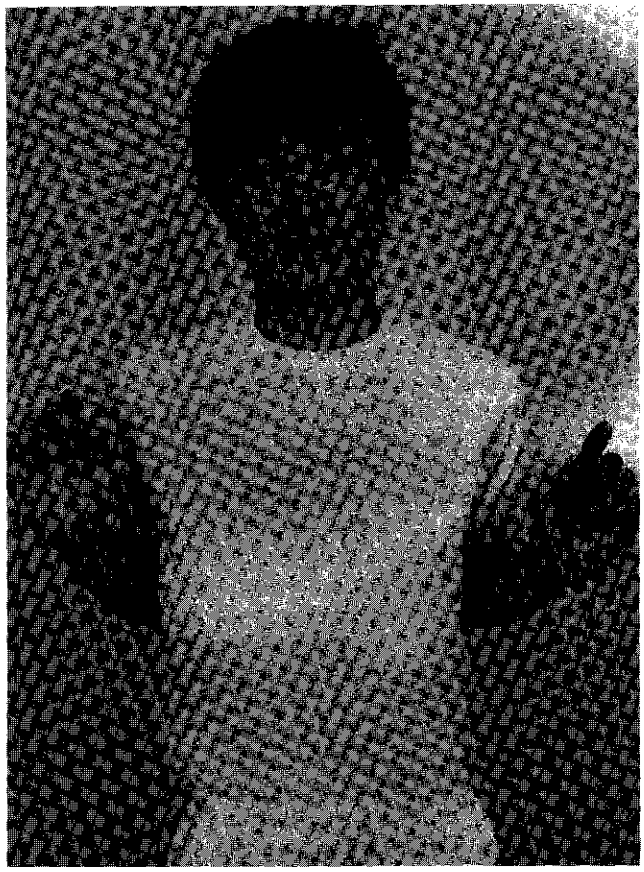

Figure 1

The "stick-up" position with the forearms elevated, the elbows held by the sides and the shoulders forced back.

†Model PA13, Medasonics, Inc, Mountain View, CA
††Model PRS14, Medasonics, Inc, Mountain View, CA

Results

Forty-six (32%) of the 145 individuals showed reproducible obliteration of their radial pulse detected clinically in at least one position (Table I). The "stick up" position was the most frequently positive test (23%) and Adson's the least (2%) (Table II). Bilateral compression was detected clinically in 24 (17%) of the 145 individuals in at least one position (Table III). There was no significant blood pressure difference at rest between the upper extremities of any individual studied.

PPG was positive in 49 (34%) of the 145 individuals tested (Table I). The PPG was positive most frequently with the "stick up" position (21%) (Table IV).

	Left arm	Right arm	Bilateral	Total
Clinical	15	7	24	46
PPG	22	8	19	49

Table I

Clinical and PPG detection of pulse obliteration in at least one position.

	Posture					
	Rest	90°	180°	SU	Military	Adson
Males	0	5	8	23	6	3
Females	0	5	9	10	3	0
Total	0	10	17	33	9	3

Table II

Clinical determination of arterial compression in 145 individuals. They were examined at rest, with the arms abducted to 90° then 180°, in a "stick up" position (SU), standing in an exaggerated military posture and using the Adson maneuver. Clinical findings were positive in 46 (32%) in at least one position. The results for each position and sex distribution are shown.

	Posture					
	Rest	90°	180°	SU	Military	Adson
Left	0	3	5	14	2	1
Right	0	5	5	4	2	2
Bilateral	0	4	14	30	10	0
Total limbs	0	12	24	48	14	3

Table III

Bilateral compression was detected clinically in 24 (17%) of the 145 individuals in at least one position. The table shows the relationship of all positions and clinical detection of pulse obliteration in 290 limbs examined.

	Posture					
	Rest	90°	180°	SU	Military	Adson
Males	0	4	7	21	2	11
Females	0	1	2	9	4	3
Total	0	5	9	30	6	14

Table IV

Photoplethysmographic (PPG) determination of arterial compression. PPG was positive in 49 (34%) in at least one position. The results for each position and sex distribution are shown.

Bilateral compression was detected by PPG in 19 (13%) of the 145 individuals in at least one position (Table V).

There was poor correlation between clinical detection of pulse obliteration and PPG (Table VI). Thirty-five limbs (51%) of the 68 limbs with a positive PPG were clinically without pulse loss. Clinical pulse obliteration was observed in 71 limbs, 38 (54%) of which did not have a positive PPG (Table VI).

Although 74% of the 145 individuals studied used their right hand for some activities, 93% wrote with their right hand. Pulse obliteration was more commonly demonstrated in the left arm (Table I). However no statistically significant relationship was demonstrated between hand dominance and arterial pulse obliteration. Neither was any statistically significant relationship demonstrated between sex, occupation or age and arterial compression (Chi-squared analysis, $p > 0.05$).

Discussion

This study confirms that upper extremity arterial compression is common in individuals without symptoms of thoracic outlet neurovascular compression. The prevalence of 32% in a heterogeneous group of young adults is lower than that observed by others.

	Posture					
	Rest	**90°**	**180°**	**SU**	**Military**	**Adson**
Left	0	3	6	12	2	5
Right	0	2	2	4	3	6
Bilateral	0	0	2	26	4	4
Total limbs	0	5	10	42	9	15

Table V

Bilateral compression was detected by PPG in 19 (13%) of the 145 individuals in at least one position. The table shows the relationship of all positions and PPG detection of pulse obliteration in 290 limbs examined.

		Photoplethysmography		
		Positive	**Negative**	**Total**
Clinical Testing	Positive	33	38	71
	Negative	35	184	219
	Total	68	222	290

Sensitivity = 33/68 = 49%
Selectivity = 184/222 = 83%
Positive predictive value = 33/71 = 46%
Negative predictive value = 184/219 = 84%

Table VI

Comparison of clinical findings and PPG for 290 limbs in 145 individuals tested.

The difference may be due to the variable prevalence in the populations studied and the effort made to obliterate the pulse. In 1945, Wright[10] published a study of 150 healthy male military recruits showing that with hyperabduction of the arm, pulse obliteration could be produced in about 60% of the recruits. If the arm and shoulder were then forced posteriorly the prevalence increased to over 80%. Telford and Mottershead studied 120 medical students.[11] They observed pulse obliteration in about 50% with abduction of the arm but with forced hyperabduction this increased to 90%. Other authors[1,12] have shown similar changes in smaller studies.

Because arterial compression is common in asymptomatic individuals, we agree with other authors[2,6] that detection of arterial compression, either clinically or by PPG, is not diagnostic of thoracic outlet syndrome. However detection of arterial compression complements clinical[2] and electrophysiological[13] diagnosis of thoracic outlet syndrome in patients with a suspected arterial basis for their symptoms. Symptoms due to arterial compression may be extremely difficult to differentiate from symptoms due to neural compression and limb loss can result if all parasthesiae are assumed to be neurological and arterial pathology is overlooked.[14]

This study has also shown a poor correlation between clinical and PPG detection of arterial pulse loss. In one of the few studies of PPG and arterial compression Gergoudis and Barnes[6] found a prevalence of 60% in a study of 130 unspecified normal individuals, using a greater than 75% reduction in PPG amplitude as the criteria for an abnormal PPG. The prevalence was 12% when the PPG was considered positive with complete loss of pulsation. We have found considerable variability in PPG amplitude despite attempts to standardize PPG recordings. For this reason, we chose complete loss of arterial pulsation as a better end-point to classify PPG changes with posture. Using this criteria, the prevalence of 35% in this study was higher than the 12% established by Gergoudis and Barnes.[6] The difference may be attributed to the use of the "stick up" position as the prevalence in our study would have been only 21% if the position had not been used. We have found the "stick up" position to be a simple way to test for arterial compression. Most patients can readily adopt it and the radial pulse is easier to feel than it is when the arm is hyperabducted.

The finding of clinical pulse loss without a positive PPG, which occurred in 38 limbs tested (Table VI), may be explained in part by hemodynamic changes that occur as the arm is elevated to the hyperabducted position. Arterial pressure at the wrist decreases[15,16] and the pulse may therefore be difficult to feel even though there is sufficient pulsatile flow for a normal PPG recording. In 35 limbs, the pulse was thought present on clinical examination even though the PPG recording in the same position was abnormal (Table VI). This discrepancy may be due to observer error or relate to the difficulty of palpating the pulse in the hyperabducted position.

Using either clinical or PPG criteria of arterial compression, no significant difference in prevalence was demonstrated on the basis of sex, occupation, hand dominance or age.

Conclusions

There is wide variation in the reported incidence of arterial compression in asymptomatic individuals. The long term significance of arterial compression is unknown but is considered benign. No relationship between arterial compression and sex, occupation, hand dominance or age was found. Adson's test was the least useful way to demonstrate arterial compression. However, a "stick up" position was an effective posture to test for arterial compression. PPG and clinical findings of arterial compression should be interpreted with caution as there is considerable overlap between clinical and PPG detection of arterial compression. The tests are not diagnostic of thoracic outlet syndrome.

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