EVALUATION OF PERIPHERAL ARTERIAL PRESSURE ON THE THUMB FOLLOWING RADIAL ARTERY CANNULATION

TORBEN PALM

SUMMARY

The effects of cannulation of the radial artery were studied in 23 patients. Distal arterial pressure on the thumb, measured during radial or ulnar artery compression, was compared with the result of a modified Allen test performed before operation. Distal arterial pressure on the thumb was monitored for approximately 10 days after removal of the cannula. It was found that radial artery thrombosis, as defined by a thumb arterial pressure of less than 10 mm Hg during ulnar artery compression, occurred with a frequency of about 40% depending on the duration of cannulation. Furthermore, thrombosis of the radial artery resulted in a decrease in perfusion pressure in the thumb of from 17 to 33% of the values before cannulation. However, a satisfactory result from a carefully performed Allen test seems to ensure that post-thrombotic perfusion pressure in the thumb is not decreased to values associated with compromised nutrition of the tissues.

Monitoring of the critically ill patient during major surgery often necessitates prolonged arterial cannulation. By this technique continuous arterial pressure measurement and repeated blood sampling for blood-gas analysis are possible. Although serious vascular complications can occur in relation to arterial puncture and cannulation (Mortensen, 1967), the nutritional supply of the hand seems to be relatively free from interference following the use of the radial artery. However, recent documentation has indicated that thrombosis of the radial artery, following cannulation, occurs surprisingly frequently (Bedford and Wollman, 1973). The well-developed collateral circulation in the hand through the hand arcade which connects directly the radial and ulnar arteries may explain these findings.

Since absent ulnar pulsation and an insufficiently developed or absent ulnar artery have been reported (Friedmann, 1970) in 10 out of 290 healthy subjects, an assessment of hand blood flow is of crucial importance before cannulation of the radial artery. Allen described a test which, in various modifications, has been used widely for this purpose (Allen, 1929). However, this test is based mainly on a subjective estimate of capillary refilling. Recently, a method of measuring distal arterial pressure has been described (Gundersen, 1972). The aims of the present study were:

1. to relate the results of measuring arterial pressure on the thumb to the Allen test;
2. to monitor the arterial pressure on the thumb following removal of the arterial catheter (to determine the frequency of arterial thrombosis);
3. to measure the arterial pressure on the thumb following radial artery occlusion to determine whether, in spite of a negative Allen test, any decrease in perfusion pressure occurs.

PATIENTS AND METHODS

Patients undergoing open heart and major vascular surgery were investigated.

The Allen test was performed as follows: the patient was asked to clench the fist for 30 s. Both the ulnar and the radial arteries were compressed by the examiner. The hand was opened loosely, avoiding hyperextension of the wrist, and the compression of the ulnar artery was released. This procedure was repeated for the radial artery. The test was judged positive if capillary refilling was not complete within 6 s (Kaminski and Barnes, 1976).

Distal arterial pressure was measured on the thumb (Gundersen, 1972). This method was based on the conventional pneumatic cuff principle. A specially designed cuff was placed around the proximal phalanx of the thumb. A mercury-in-rubber strain-gauge (Parks Electronics, Oregon) was placed around the distal phalanx. This acted as a volume detector. After inflation of the cuff to about 30 mm Hg greater than the patient's systolic arterial pressure, the pressure in the cuff was released slowly until a change in the thumb volume was registered on the strain-gauge plethysmograph, indicating that pulse waves could pass the cuff. The cuff and strain-gauge are shown...
in place on the thumb in figure 1, and a typical plethysmograph record is presented in figure 2.

The Allen test was performed on the day before operation and distal arterial pressure was measured on the thumb. Measurement of distal arterial pressure was performed with and without compression of the ulnar and radial arteries successively. If the Allen test was positive, or if the distal arterial pressure (when compressing the radial artery) was less than 40 mm Hg, cannulation was avoided.

Cannulation was performed, following infiltration of the skin with local anaesthetic, using a polypropylene cannula (Argyle Medicut, gauge 20) inserted percutaneously. The cannula was left in place until the patient’s condition had improved sufficiently to permit its removal. While in situ, the catheter was flushed continuously with physiological saline (heparinized). Blood samples were taken when required for blood-gas analysis, but no other samples were taken from the arterial line.

Following operation, thumb arterial pressures were monitored daily; in a few patients this was done while the catheter was still in place, and in all patients from the day of removal. Since it has been reported (Bedford and Wollman, 1973) that thrombosis can occur as late as 1 week following removal of the cannula, the patients were examined for at least 10 days after the removal. A thumb arterial pressure less than 10 mm Hg, when compressing the ulnar artery, was considered to be an indication of thrombosis of the radial artery. To evaluate any decrease in perfusion pressure to the hand as a result of an occluded radial artery, thumb arterial pressure was measured without ulnar artery compression.

In one patient the validity of the strain-gauge method was tested against systemic arterial pressure measured by a transducer (Statham P23) after cannulation of the radial artery. After making sure that the radial artery was patent still (distal thumb arterial pressure was normal when the ulnar artery was compressed) simultaneous measurements of thumb arterial pressure and radial artery pressure were obtained. This procedure was performed before surgery and by varying the concentration of halothane in the inspired air and thereby the level of anaesthesia, a wide range of systemic arterial pressure could be obtained.

RESULTS

Twenty-three patients (eight females and 15 males) were investigated. Their ages ranged from 35 to 65 yr. A positive Allen test was noted in the preoperative examination in two patients. In one there was no ulnar pulsation, whereas ulnar pulsation could be detected readily in the other patient. In both instances thumb arterial pressure was equal to measured arm arterial pressure when there was no compression of the radial artery, but decreased to less than 10 mm Hg during compression. Another patient had a negative Allen test although slow refilling during radial artery compression was noted. Thumb arterial pressure was 40 mm Hg during radial artery compression. In these three patients cannulation was avoided. The remaining 20 patients were deemed suitable for cannulation on account of negative Allen tests and adequate distal arterial pressure measurements.

Table I shows typical values obtained for thumb arterial pressures associated with an uncomplicated
Cannulation. Compression of the radial artery decreased thumb arterial pressure to about 60–70% of systolic arm pressure, whereas ulnar artery compression did not affect the thumb pressure.

Table II presents data from a patient with radial artery thrombosis. A 72% decrease in thumb perfusion pressure was noted before operation during radial artery compression. This decrease was greater on the 7th day following removal of the cannula, but improvement was noted by the 13th day. No thumb arterial pressure could be measured when the ulnar artery was compressed.

Eight patients (40%) developed arterial thrombosis, as defined by a thumb arterial pressure of less than 10 mm Hg during compression of the ulnar artery. The decreases in thumb perfusion pressure are shown in Table III. In nearly all these patients an improvement was observed during the period of measurement (10–13 days). Table III shows also the duration of cannulation in the eight patients who developed radial artery thrombosis subsequently.

Table IV presents the thumb arterial pressure as a percentage of the arm systolic arterial pressures on the first and last days of measurement following removal of the cannula in the 12 patients who did not show any sign of radial artery thrombosis. The duration of the cannulations are shown also.

Nutritional disturbances in the hand were not seen in the present study, but in one patient a 2 \times 2 cm area of skin necrosis developed about 8 cm proximal to the puncture site on the volar antebrachial region.

The relationship between the arterial pressure and thumb arterial pressure is shown in Table V. In nearly all these patients an improvement was observed during the period of measurement (10–13 days). Table V shows also the duration of cannulation in the eight patients who developed radial artery thrombosis subsequently.

Table VI presents the thumb arterial pressure as a percentage of the arm systolic arterial pressures on the first and last days of measurement following removal of the cannula in the 12 patients who did not show any sign of radial artery thrombosis. The duration of the cannulations are shown also.

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**Table I. Arm and thumb arterial pressure measurements (mm Hg) in one patient with an uncomplicated cannulation. Numbers in parentheses are values of thumb arterial pressure expressed as a percentage of arm arterial systolic pressure.**

<table>
<thead>
<tr>
<th>Arterial pressure (mm Hg)</th>
<th>Thumb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm (uncompr.)</td>
<td>(rad. compr.)</td>
</tr>
<tr>
<td>Before operation</td>
<td>120</td>
</tr>
<tr>
<td>After removal</td>
<td>120</td>
</tr>
<tr>
<td>1 day</td>
<td>120</td>
</tr>
<tr>
<td>10 days</td>
<td>120</td>
</tr>
</tbody>
</table>

rad. = radial; uln. = ulnar; compr. = compression; uncompr. = uncompressed.

**Table II. Arm and thumb arterial pressure measurements (mm Hg) in one patient with radial artery thrombosis (as defined in text). Numbers in parentheses are values of thumb arterial pressure expressed as a percentage of arm arterial systolic pressure.**

<table>
<thead>
<tr>
<th>Arterial pressure (mm Hg)</th>
<th>Thumb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm (uncompr.)</td>
<td>(rad. compr.)</td>
</tr>
<tr>
<td>Before operation</td>
<td>140</td>
</tr>
<tr>
<td>After removal</td>
<td>130</td>
</tr>
<tr>
<td>1 day</td>
<td>120</td>
</tr>
<tr>
<td>7 days</td>
<td>130</td>
</tr>
<tr>
<td>13 days</td>
<td>115</td>
</tr>
</tbody>
</table>

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**Table III. Changes in thumb arterial pressure (as a percentage of arm arterial systolic pressure), following removal of the cannula, in eight patients with arterial thrombosis. The duration of cannulation is shown also.**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Day after removal of cannula</th>
<th>Cannulation time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Last</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>70</td>
<td>78</td>
</tr>
<tr>
<td>2</td>
<td>75</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>83</td>
<td>93</td>
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<td>4</td>
<td>67</td>
<td>86</td>
</tr>
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<td>5</td>
<td>76</td>
<td>97</td>
</tr>
<tr>
<td>6</td>
<td>79</td>
<td>78</td>
</tr>
<tr>
<td>7</td>
<td>70</td>
<td>83</td>
</tr>
<tr>
<td>8</td>
<td>74</td>
<td>80</td>
</tr>
</tbody>
</table>

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**Table IV. Changes in thumb arterial pressure (as a percentage of arm arterial systolic pressure), following removal of the cannula, in 12 patients showing no evidence of arterial thrombosis. The duration of cannulation is shown also.**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Day after removal of cannula</th>
<th>Cannulation time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Last</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>101</td>
<td>97</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>99</td>
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<td>4</td>
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<td>5</td>
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<td>7</td>
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<td>105</td>
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<td>8</td>
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<td>94</td>
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<td>10</td>
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<td>100</td>
</tr>
<tr>
<td>11</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>12</td>
<td>100</td>
<td>101</td>
</tr>
</tbody>
</table>
Art.
radialis (minHg)
150
130
110
90
70
70 90 110 130 150
Strain
gauge (mm Hg)
y = 1.11 x - 3.8
r = 0.98

Fig. 3. Relationship between arterial pressure measured i.a.,
and by strain-gauge on the thumb.

measured by direct arterial puncture and by strain-
gauge is shown in figure 3. There was a good
correlation over the range 80-170 mm Hg. The direct
intra-arterial pressure was found to be about
4 mm Hg greater than the pressure measured
indirectly.

DISCUSSION
The validity of the strain-gauge method in the mea-
surement of distal arterial pressure has been investi-
gated previously (Gundersen, 1972). It was found
that the arterial pressure in the thumb should, under
normal conditions, almost equal the arterial pressure
as measured by the conventional arm cuff. With an
unchanged systemic pressure the variation in serial
measurements was about 5%. To be certain that
there was good agreement between the strain-gauge
method and direct intra-arterial pressure in our study,
simultaneous determinations of arterial pressure using
a radial artery cannula and the thumb strain-gauge
were performed in one of our patients (fig. 3). Follow-
ing this it was assumed that any decreases in the
thumb pressure, greater than 5%, relative to upper
arm pressure could be taken as an indication of
occlusive lesions in the peripheral arterial system.

Experience with distal arterial pressure measure-
ments, mainly in lower extremities, has shown that
pressures of as little as 40 mm Hg seldom cause
trophic disturbances although intermittent claudica-
tion may be present. At pressures of less than 40 mm
Hg ulceration and delayed healing of wounds may
occur and at pressures less than 20 mm Hg the
extremity is threatened by gangrene (Lassen et al.,
1975). This is the reason for choosing 40 mm Hg
as the lower limit of perfusion pressure if the radial
artery is thrombosed. In only one patient was there
disagreement between the Allen test and measure-
ment of distal pressure. As the pressure was deter-
mined on three occasions with unequivocal results,
and as the refilling in this situation was slow, it
might be concluded that 6 s is too much time to
allow for refilling. In all other patients good agree-
ment was found between the result of the Allen
test and the thumb pressure measurements.

Previous investigations on the frequency of throm-
bosis following radial artery cannulation, using the
Doppler flowmeter technique, have given variable
results. Ryan and others (1973) found evidence for
arterial thrombosis in 12 out of 13 cannulations.
Katsuyuki, Edmonds and Conn (1976), studying can-
nulations during paediatric surgery, reported a fre-
quency of thrombosis in the radial artery of 51%.
They showed additionally that increasing the dura-
tion of cannulation seemed to increase the likelihood
of thrombosis. This is in good agreement with the
findings of Bedford and Wollmann (1973) in adult
patients. They found an overall frequency of throm-
bosis of 38%; with less than 20 h of cannulation the
frequency of thrombosis was 25% and increased to
50% in cannulations of greater duration. The present
results, 40% thrombosis overall, seem to be in accord
with these earlier results, and the finding of, on
average, a longer period of cannulation in those
patients who developed thrombosis supports the rela-
tionship between prolonged cannulation and an in-
creased risk of thrombosis. The use of a smaller
needle (gauge 20 compared with Bedford's gauge 18)
as used in the study did not seem to decrease the
incidence of thrombosis.

As is agreed generally, the presence of the hand
arcade is responsible for there being only a small
number of complications following thrombosis of the
radial artery. It is known (Ryan et al., 1973) that
either the ulnar or the radial arteries can be dominant
in the blood supply of the hand. In the present study
it was noted that the decrease in thumb arterial pres-
sure, following radial artery thrombosis, was variable
—from 17 to 33%. The same pattern was seen in the
preoperative measurements where arterial occlusion
was simulated by compression. This phenomenon
could be a result of individual variability in the
arterial dominance. The improvement in perfusion
pressure, observed during the first 10-13 days after
removal of the cannula, might be explained likewise
by the patent artery gradually "taking over" the
blood supply. It was felt that, in the present investi-
evaluation, the duration of this study was too short to allow for the possibility of recanalization of the thrombosed vessel. In no instance did the decrease in thumb pressure exceed 47%, which was in good agreement with the lack of any clinical evidence of impaired nutrition of the thumb. In one patient an area of skin necrosis was seen on the volar aspect of the forearm. This finding was associated with thrombosis of the radial artery. This lesion was similar to that described by Wyatt, Glaves and Cooper (1974), and must be a result of occlusion of cutaneous branches emerging directly from the radial artery.

In conclusion, it appears that thrombosis frequently follows cannulation of the radial artery but, because of the hand arcade, perfusion pressure in the thumb area does not seem to be decreased to low values provided the Allen test is performed carefully, and gives a satisfactory result, before cannulation. Although severe complications have been reported (Dalton and Laver, 1971; Katz et al., 1974), they seem to be uncommon. As important information can be obtained by radial artery cannulation in the critically ill patient, this procedure can be recommended still, provided the indications are appropriate.

REFERENCES


EVALUATION DE LA TENSION ARTÉRIELLE PERIPHERIQUE SUR LE POUCHE LA SUITE DE L'INTRODUCTION D'UNE CANULE DANS L'ARTÈRE RADIALE

RESUME

On a étudié sur 23 patients les effets de l'introduction d'une canule dans l'artère radiale. On a comparé la tension artérielle distale mesurée sur le pouce pendant la compression artérielle radiale ou cubitale, avec le résultat d'un test d'Allen modifié effectué avant une intervention chirurgicale. On a surveillé pendant 10 jours environ, après avoir retiré la canule, la tension artérielle distale sur le pouce. On a trouvé qu'il s'était produit une thrombose artérielle radiale, définie par une tension artérielle sur le pouce inférieure à 10 mm Hg pendant la compression artérielle cubitale, dans environ 40% des cas selon la durée du maintien en place de la canule. De plus, la thrombose de l'artère radiale a entraîné une diminution de la pression de perfusion dans le pouce, allant de 17 à 33% des valeurs antérieures à la mise en place de la canule. Toutefois, lorsqu'un test d'Allen soigneusement effectué donne un résultat satisfaisant, cela semble assurer que la pression de perfusion dans le pouce, après la thrombose, n'est pas inférieure aux valeurs associées à une nutrition compromise des tissus.

BEURTEILUNG DES PERIPHEREN ARTERIELLEN DRUCKES AUF DEN DAUMEN NACH KANÜLENEINFÜHRUNG IN DIE RADIALARTERIE

ZUSAMMENFASSUNG

EVALUACION DE LA TENSION ARTERIAL PERIFERICA EN EL DEDO PULGAR CONSECUTIVA A LA ENCANULACION DE ARTERIA RADIAL

SUMARIO
Se estudiaron en 23 pacientes los efectos de la encanulación de la arteria radial. La tensión arterial distal en el dedo pulgar, medida durante compresión radial o ulnar arteriales, fue comparada con el resultado de una prueba de Allen modificada, antes de la operación. Se comprobó la tensión arterial distal en el dedo pulgar durante aproximadamente 10 días tras la retirada de la cánula. Se halló que la trombosis de arteria radial, definida por una tensión arterial de dedo pulgar inferior a 10 mm Hg durante compresión de la arteria ulnar, ocurrió con una frecuencia de un 40% según la duración de la encanulación. Además, la trombosis de la arteria radial resultó en un descenso en la presión de perfusión en el dedo pulgar del 17 al 33% de los valores anteriores a la encanulación. Sin embargo, un resultado satisfactorio de una prueba de Allen cuidadosamente realizada parece asegurar que la presión de perfusión trombótica en el dedo pulgar no es disminuida hasta valores asociados con una nutrición arriesgada de los tejidos.