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Plasma Metanephrines in the Diagnosis of Pheochromocytoma

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- **Objective:** To examine whether tests for plasma metanephrines, the α-methylated metabolites of catecholamines, offer advantages for diagnosis of a pheochromocytoma over standard tests for plasma catecholamines or urinary metanephrines.
- **Design:** Cross-sectional study.
- **Setting:** 3 clinical specialist centers.
- **Patients:** 52 patients with a pheochromocytoma; 67 normotensive persons and 51 patients with essential hypertension who provided reference values; and 23 patients with secondary hypertension and 50 patients with either heart failure or angina pectoris who served as comparison groups.
- **Measurements:** Plasma concentrations of catecholamines (norepinephrine and epinephrine) and metanephrines (normetanephrine and metanephrine) were measured in all patients. The 24-hour urinary excretion of metanephrines was measured in 46 patients with pheochromocytoma.
- **Results:** Pheochromocytomas were associated with increases in plasma concentrations of metanephrines that were greater and more consistent than those in plasma catecholamine concentrations. No patient with a pheochromocytoma had normal plasma concentrations of both normetanephrine and metanephrine. The sensitivity of these tests was 100% (52 of 52 patients [95% CI, 94% to 100%]), and the negative predictive value of normal plasma concentrations of metanephrines was 100% (162 of 162 patients). Tests for plasma catecholamines yielded eight false-negative results and a sensitivity of 85% (44 of 52 patients [CI, 72% to 93%]). The negative predictive value of normal plasma concentrations of catecholamines was 95% (156 of 164 patients). Tests for urinary metanephrines yielded five false-negative results and a sensitivity of 89% (41 of 46 patients [CI, 76% to 96%]). Because no statistical difference was noted in the number of false-positive results between tests for plasma metanephrines (15%) and tests for plasma catecholamines (18%), the specificities of the two tests did not differ.
- **Conclusions:** Normal plasma concentrations of metanephrines exclude the diagnosis of pheochromocytoma, whereas normal plasma concentrations of catecholamines and normal urinary excretion of metanephrines do not. Tests for plasma metanephrines are more sensitive than tests for plasma catecholamines or urinary metanephrines for the diagnosis of pheochromocytoma.


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Pheochromocytoma is a tumor of chromaffin cells that usually presents as hypertension. The tumor has potentially life-threatening consequences if it is not promptly diagnosed, located, and removed. Evidence of excessive production of catecholamines is essential for diagnosis of the tumor. Traditional tests have relied on measurements of the 24-hour urinary excretion of catecholamines (norepinephrine and epinephrine) or of the products of catecholamine metabolism (1-4).

Because of the common problems of incompleteness and inconvenience associated with 24-hour urine collections, clinicians have long sought a diagnostic test based on sampling of antecubital venous blood. Measurements of plasma catecholamines are useful in this respect (4, 5). However, patients with a pheochromocytoma can have plasma concentrations of catecholamines that fall within the range of those in patients with essential hypertension (4, 6) (that is, false-negative results). In addition, emotional distress or pathologic conditions other than pheochromocytoma (such as heart failure) can produce abnormally high catecholamine concentrations (7, 8) (that is, false-positive results). Glucagon stimulation and clonidine suppression testing can enhance the accuracy of plasma catecholamine determinations in the diagnosis of pheochromocytoma (9, 10). These tests, however, can still yield false-negative or false-positive results (9-11); they also require considerable time and effort. The search has continued for a single simple, highly sensitive and specific blood test with which to confirm the presence of the tumor in patients with pheochromocytoma. We studied the diagnostic accuracy of tests for specific catecholamine metabolites for this purpose, notably the metanephrines—normetanephrine and metanephrine.

An understanding of why plasma metanephrines may be particularly useful for diagnosis of pheochromocytoma requires an understanding of catecholamine metabolism. Norepinephrine and epinephrine are first metabolized intraneuronally by deamination to dihydroxycphenylglycol or extraneuronally by α-methylation to the metanephrines (12). Because most dihydroxycphenylglycol is formed from norepinephrine leaking from neuronal stores and little is formed from circulating catecholamines (13, 14), plasma levels of this metabolite are relatively insensitive to the release of catecholamines into the circulation from a pheochromocytoma (6, 15). The formation of most methoxycphenylglycol from dihydroxycphenylglycol (14) and the formation of most vanillylmandelic acid from methoxycphenylglycol within the liver (16) explains
why a test for vanillylmandelic acid is also a poorer marker for pheochromocytoma than other tests (17). In contrast, preferential metabolism of circulating catecholamines compared with neuronal catecholamines by extra-neuronal pathways (14) suggests that the metanephrines—as extraneuronal metabolites—may provide good markers for release of catecholamines from a pheochromocytoma. Furthermore, substantial production of metanephrines within adrenal tissue (18) suggests that metanephrines may be produced within the tumor itself.

In humans, metanephrines are extensively sulfate-conjugated (18, 19). Assays of metanephrines in urine depend on measurements after deconjugation to free metanephrines (19) so that measurements represent the sum of free and conjugated metabolites (total metanephrines). In contrast, good sensitivity of the assay for plasma metanephrines (20) enables measurements of both free and total metanephrines.

We compared the sensitivity, specificity, and positive and negative predictive values of tests for plasma free and total metanephrines with those of tests for plasma catecholamines and urinary total metanephrines. Study participants included a relatively large sample of patients with pheochromocytoma, patients with essential hypertension or secondary hypertension from causes other than pheochromocytoma, and patients with either heart failure or angina pectoris in whom sympathetically mediated catecholamine release would be expected to be increased.

Methods

Patients

Fifty-two patients with a histologically proven pheochromocytoma were studied. Thirty patients were studied retrospectively, and 22 were studied before the final diagnosis was made. The pheochromocytoma was benign in 39 patients and malignant in 13. Sixty-seven healthy, normotensive persons and 51 patients with essential hypertension or secondary hypertension from causes other than pheochromocytoma were studied before the final diagnosis was made. The pheochromocytoma was benign in 39 patients and malignant in 13.

Blood and Urine Samples

All patients refrained from ingesting methylxanthine-containing food products and from smoking after midnight on the day before blood sampling. Blood was collected from an indwelling catheter in an antecubital vein after the patients had rested supine for 20 minutes. In 39 patients with heart failure and 15 with secondary hypertension, arterial blood was obtained through an indwelling arm arterial catheter. Blood samples were collected into presoaked tubes containing heparin or EDTA and glucose one and were centrifuged within 30 minutes to separate the plasma, which was stored frozen until assayed. All plasma catecholamine and urinary metanephrine assays were done within 2 weeks of sample collection. Seven of the 52 pheochromocytoma samples were assayed for plasma metanephrines after being stored at −80°C for more than 2 years (range, 2 to 8 years), whereas the remaining 45 samples were assayed within 2 years of collection (22 samples within 4 weeks). In 46 of the 52 patients with pheochromocytoma, a 24-hour urine collection was obtained, with 30 mL of 6-M hydrochloric acid used as a preservative.

Analytic Methods

Plasma metanephrines were assayed at the National Institutes of Health (NIH) using liquid chromatography with electrochemical detection (20). Concentrations of total metanephrines (the sum of concentrations of free and sulfonated conjugated metanephrines) were measured after incubation of 0.25 mL of plasma with 0.1 units of sulfatase (Sigma Chemical Company, St. Louis, Missouri) at 37°C for 30 minutes. The detection limits were 0.013 nmol/mL for normetanephrine and 0.019 nmol/mL for metanephrine. At a plasma normetanephrine concentration of 0.31 nmol/mL and a metanephrine concentration of 0.21 nmol/mL, the interassay coefficients of variation were 12.2% for normetanephrine and 11.2% for metanephrine. As previously reported (20), the presence of acetaminophen in samples of plasma can substantially interfere with measurements of plasma normetanephrine concentrations. Therefore, this analgesic must not be used by patients for several days before blood samples are collected. No analytic interference of various other drugs with this assay has been shown (20).

Plasma catecholamines were assayed using liquid chromatography. Electrochemical detection was used for quantification at the NIH (21), and fluorometric detection was used at St. Radboud University Hospital, Nijmegen, the Netherlands (22). At the NIH, the detection limits were 0.006 nmol/mL for noradrenaline and 0.010 nmol/mL for adrenaline. At a plasma noradrenaline concentration of 2.4 nmol/mL and an adrenaline concentration of 0.39 nmol/mL, the interassay coefficients of variation were 6.5% for noradrenaline and 11.4% for adrenaline. At St. Radboud University Hospital, the detection limits for noradrenaline and adrenaline were 0.002 nmol/mL and 0.003 nmol/mL, respectively. At plasma concentrations of 1.02 nmol/mL for noradrenaline and 0.15 nmol/mL for adrenaline, interassay coefficients of variation were 9.5% for noradrenaline and 7.2% for adrenaline.

Urinary concentrations of metanephrines were measured according to a previously described method (23); the upper reference limit of the normal range for the 24-hour urinary output of metanephrines was 6.8 μmol/d.

Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normotension</th>
<th>Essential Hypertension</th>
<th>Secondary Hypertension</th>
<th>Heart Failure or Angina Pectoris</th>
<th>Pheochromocytoma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients, n</td>
<td>67</td>
<td>51</td>
<td>23</td>
<td>50</td>
<td>52</td>
</tr>
<tr>
<td>Mean age ± SD (range), y</td>
<td>39 ± 12 (20-72)</td>
<td>43 ± 13 (16-69)</td>
<td>48 ± 14 (20-69)</td>
<td>57 ± 11 (34-81)</td>
<td>39 ± 13 (11-71)</td>
</tr>
<tr>
<td>Male/female, n/n/n</td>
<td>40/27</td>
<td>24/27</td>
<td>14/9</td>
<td>42/8</td>
<td>28/24</td>
</tr>
<tr>
<td>Study center (NIH/SR/SH), n/n/n</td>
<td>36/31/0</td>
<td>15/0</td>
<td>17/15</td>
<td>13/7/30</td>
<td>41/11/0</td>
</tr>
</tbody>
</table>

* NIH = National Institutes of Health; SH = Sahlgrens Hospital; SR = St. Radboud University Hospital.
Because plasma concentrations of catecholamines and meta-
nephrines were not normally distributed, only medians and ranges
are presented for these concentrations. Differences in plasma
concentrations of metanephrines and catecholamines among pa-
tients with pheochromocytoma and other groups were tested
using the Kruskal-Wallis test. We assessed relations among vari-
ables using the Spearman rank correlation coefficient.

Normal distributions of plasma concentrations of catechol-
amines and metanephrines were obtained after logarithmic trans-
formation of the data. Thus, upper reference limits, defined as
the 97.5th percentile, were determined after logarithmic trans-
formation of individual values for the combined data from nor-
motensive persons and those with essential hypertension (118
persons). The 97.5th percentiles were calculated from the anti-
logarithm of the mean plus 2 standard deviations of the trans-
formed data. A false-negative result of a test for plasma meta-
nephrines in a patient with pheochromocytoma was defined as
plasma concentrations of both normetanephrines and metaneph-
rines that were below their respective upper reference limits.
Similarly, a false-negative result of a test for plasma catechol-
amines was defined as plasma concentrations of norepinephrine
and epinephrine that were below their respective upper refer-
ce limits. A false-positive result of a test for plasma meta-
nephrines in patients without pheochromocytoma was defined as
a plasma concentration of either normetanephrine or metanephrine
that was equal to or above the upper reference limits. Similarly,
a false-positive result of a test for plasma catechol-
amines was defined as a plasma concentration of either norepi-
 nephrine or epinephrine that was equal to or greater than the
upper reference limits. We calculated the sensitivity and speci-
licity (with 95% CIs), pretest and post-test probabilities, and
positive and negative predictive values for each analyte (24).

Differences in tumor-associated elevations in plasma catechol-
amine concentrations and free and total metanephrine concen-
trations were assessed from the fold-increases in plasma concen-
trations of compounds in patients with pheochromocytoma that
were greater than median values in the normotension and essen-
tial hypertension reference groups. We computed mean ± SE
fold-increases after logarithmic transformation of individual fold-
increases. We estimated differences among fold-increases by
analysis of variance; post hoc tests were done with the Scheffe
F-test.

Receiver-operating characteristic curves were constructed from
the relation between the rates of true-positive and false-positive
results (that is, sensitivity compared with 1 minus the specificity)
for diagnosis of pheochromocytoma that are based on different
upper reference limits for each analyte (25). These curves en-
abled us to compare the sensitivity and specificity of tests for
plasma metanephrines for diagnosing pheochromocytoma with
those of tests for plasma catecholamines, as a function of differ-
ent upper reference limits for each analyte. The areas under the
receiver-operating characteristic curves for plasma catechol-
amines and metanephrines were calculated as summary measures
of the diagnostic power that were independent of upper refer-
ce limits. We calculated the difference between the two areas
and tested them according to the method of Hanley and McNeil
(26).

Results

Plasma Concentrations of Catecholamines and Free and
Total Metanephrines

Plasma concentrations of free normetanephrine and meta-
nephrine in the normotension and hypertension refer-
ce groups were not normally distributed until the
data were logarithmically transformed (Figure 1). Ranges
of plasma concentrations of normetanephrine and meta-
nephrine were wider and the values were considerably
higher ($P < 0.001$) in patients with pheochromocytoma
than in any other patient group (Table 2).

In each group, plasma concentrations of total meta-
nephrines were much higher than concentrations of free
metanephrines; only a small proportion (<7%) of the
normetanephrine or metanephrine in plasma was in the
free form (Table 2). Like the free metanephrines, ranges
of plasma concentrations of total metanephrines were
much wider and the values much higher ($P < 0.001$) in
patients with pheochromocytoma than in any other pa-
tient group. Similarly, ranges of plasma concentrations
of norepinephrine and epinephrine were wider in patients
with pheochromocytoma than in other groups, but only
norepinephrine concentrations were consistently higher
($P < 0.001$) in patients with pheochromocytoma than in
other groups.

Accuracy of Tests for Plasma Metanephrines

The upper reference limits were 0.66 nmol/L for plasma
normetanephrine and 0.30 nmol/L for metanephrine. Only
1 of the 52 patients with pheochromocytoma had a
plasma concentration of normetanephrine within the nor-
mal range (Figure 2, top), that is, a false-negative result.
However, this patient (patient 42; Table 3) also had an elevated plasma metanephrine concentration. Thus, when both metabolites were considered in the diagnosis rather than plasma normetanephrine alone, the number of false-negative results was reduced from 1 to 0, yielding a sensitivity and negative predictive value of 100% (Table 4). In 29 of the 191 patients (15%) without pheochromocytoma, a test for plasma normetanephrine or metanephrine yielded a false-positive result (Figure 2). Six of these 29 false-positive results were obtained in patients with renal artery stenosis or renal failure, and 16 were obtained in patients with heart failure.

### Table 2. Plasma Concentrations of Catecholamines and Metanephrines*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normotension</th>
<th>Essential Hypertension</th>
<th>Secondary Hypertension</th>
<th>Heart Failure or Angina Pectoris</th>
<th>Pheochromocytoma</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n = 67)</td>
<td>(n = 51)</td>
<td>(n = 23)</td>
<td>(n = 50)</td>
<td>(n = 52)</td>
</tr>
<tr>
<td>Normetanephrine, nmol/L</td>
<td>0.27 (0.09–0.70)</td>
<td>0.28 (0.10–0.78)</td>
<td>0.26 (0.11–2.24)</td>
<td>0.32 (0.14–22.47)</td>
<td>5.56 (0.48–172)</td>
</tr>
<tr>
<td>Metanephrine, nmol/L</td>
<td>0.15 (0.04–0.34)</td>
<td>0.14 (0.06–0.38)</td>
<td>0.21 (0.05–0.93)</td>
<td>0.22 (0.08–0.51)</td>
<td>0.47 (0.04–382)</td>
</tr>
<tr>
<td>Total normetanephrine, nmol/L</td>
<td>6.80 (2.90–24.7)</td>
<td>9.05 (2.90–15.50)</td>
<td>1.71 (3.24–31.8)</td>
<td>15.46 (4.10–352)</td>
<td>98.9 (14.5–1684)</td>
</tr>
<tr>
<td>Total metanephrine, nmol/L</td>
<td>2.03 (1.25–6.46)</td>
<td>3.90 (0.84–19.00)</td>
<td>4.96 (0.89–69.6)</td>
<td>5.03 (2.42–126)</td>
<td>7.50 (1.94–329)</td>
</tr>
<tr>
<td>Norpethadrine, nmol/L</td>
<td>1.15 (0.42–3.38)</td>
<td>1.38 (0.41–3.85)</td>
<td>1.90 (0.77–16.2)</td>
<td>1.98 (0.29–45.0)</td>
<td>11.17 (0.69–1360)</td>
</tr>
<tr>
<td>Epinephrine, nmol/L</td>
<td>0.09 (0.01–0.36)</td>
<td>0.16 (0.02–0.58)</td>
<td>0.34 (0.04–1.48)</td>
<td>0.36 (0.04–2.93)</td>
<td>0.23 (0.03–1111)</td>
</tr>
</tbody>
</table>

* Values are expressed as the median (range).

### Figure 2. Relation between plasma concentrations of normetanephrine and norepinephrine (top) and between those of metanephrine and epinephrine (bottom) in individual patients with pheochromocytoma (O) and in patients without pheochromocytoma but with false-positive normetanephrine or norepinephrine test results (*). The dashed lines represent the upper reference limits for normetanephrine or metanephrine concentrations (horizontal lines) and norepinephrine or epinephrine concentrations (vertical lines), and the gray square bounded by these lines represents the normal reference range for concentrations of metanephrines and catecholamines.

#### Accuracy of Tests for Plasma Catecholamines

The upper reference limits were 3.00 nmol/L for normetanephrine and 0.54 nmol/L for epinephrine. In contrast to the one patient with pheochromocytoma and a false-negative result of the plasma normetanephrine test, 10 patients had false-negative plasma norepinephrine test results (Figure 2, top). Of these 10 patients, 2 had elevated plasma epinephrine concentrations (patients 32 and 34; Table 3); thus, the number of false-negative results was reduced from 10 to 8 when the diagnosis was based on plasma concentrations of both norepinephrine and epinephrine rather than on norepinephrine concentrations alone. This resulted in a sensitivity of 85% (Table 4). Tests of plasma catecholamines yielded false-positive results in 35 (18%) of the 191 patients without pheochromocytoma (Figure 2). In 19 of these 35 patients, results of tests for plasma metanephrines were also false-positive. Seven of these 35 false-positive results were obtained in patients with renal artery stenosis or renal failure, and 21 were obtained in patients with heart failure.

#### Accuracy of Tests for Urinary Metanephrines

Twenty-four-hour urine specimens were obtained from 46 of the 52 patients with pheochromocytoma and were not obtained from patients in any other group. The median urinary excretion rate of metanephrines in these patients was 24.2 μmol/d (range, 2.1 to 242 μmol/d). Use of such an upper reference limit of 6.8 μmol/d for the urinary excretion of metanephrines in normotensive persons (23) yielded false-negative results in 5 of the 46 patients and a sensitivity of 89% (95% CI, 76% to 96%); all 5 patients had increased plasma concentrations of metanephrines, but only 3 had increased plasma concentrations of catecholamines. Creatinine excretion among the 5 patients with normal urinary excretion of metanephrine was within the normal range (1 to 2.5 g/d). Use of an upper reference limit of 9.5 μmol/d in hypertensive patients (4)
yielded 10 false-negative results and a sensitivity of 78% (CI, 64% to 89%).

**Accuracy of Tests for Plasma Metanephrines Compared with Tests for Catecholamines**

Tumor-associated elevations in plasma normetanephrine concentrations were 153% greater than those in plasma norepinephrine and 64% greater than those in plasma concentrations of total metanephrines (Figure 3, top). Tumor-associated elevations in plasma metanephrine concentrations were 70% greater than those in epinephrine concentrations but did not differ from those in total metanephrine concentrations (Figure 3, bottom). Increases in plasma concentrations of total metanephrines were 54% greater than in plasma concentrations of norepinephrine, whereas increases in total metanephrine concentrations were 46% greater than increases in epinephrine concentrations.

Among the 11 patients with pheochromocytoma and equivocal results of tests for normetanephrine or norepinephrine (Table 3), 17 positive results were obtained for tests for metanephrines (normetanephrine, 10 results; metanephrine, 7 results); only 4 positive results were obtained for tests for catecholamines (norepinephrine, 1 result; epinephrine, 3 results). In 7 of these 11 patients, plasma normetanephrine or metanephrine concentrations were elevated more than three times the upper reference limits for metanephrines; no patients had elevations in plasma norepinephrine or epinephrine concentrations greater than three times the respective upper reference limits.

Receiver-operating characteristic curves, which show the relation between rates of true-positive and false-positive results at different decision thresholds (that is, at different upper reference limits of plasma concentrations of metanephrines and catecholamines), confirmed the superiority of tests for plasma metanephrines over tests for plasma catecholamines for the diagnosis of pheochromocytoma, regardless of the reference limits used to define an abnormal test result (Figure 4, top). The area under the curve for plasma metanephrines (0.977 ± 0.015) was greater than that for plasma catecholamines (0.917 ± 0.027) (*P = 0.03*).

The relation between pretest and post-test probabilities—estimated from the sensitivity and specificity values listed in Table 4—show that as the prevalence rate (that is, the pretest probabilities) increases, the post-test probabilities similarly increase for diagnoses that are based on plasma concentrations of metanephrines and catecholamines (Figure 4, bottom). The negative predictive value of tests for plasma metanephrines for the diagnosis of pheochromocytoma remained constant at 100% for all prevalence rates, whereas the negative predictive value of

**Table 3. Characteristics of Tests for Plasma Metanephrines and Catecholamines**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Clinical Syndrome</th>
<th>Catecholamines</th>
<th>Metanephrines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Norepinephrine</td>
<td>Epinephrine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(umol/L)</td>
<td>(umol/L)</td>
</tr>
<tr>
<td>14</td>
<td>Sporadic</td>
<td>2.80</td>
<td>0.20</td>
</tr>
<tr>
<td>21</td>
<td>Sporadic</td>
<td>2.90</td>
<td>0.36</td>
</tr>
<tr>
<td>27</td>
<td>Sporadic</td>
<td>0.69</td>
<td>0.53</td>
</tr>
<tr>
<td>32</td>
<td>Sporadic</td>
<td>2.93</td>
<td>0.93*</td>
</tr>
<tr>
<td>34</td>
<td>Sporadic</td>
<td>1.73</td>
<td>1.26*</td>
</tr>
<tr>
<td>38</td>
<td>Sporadic</td>
<td>2.42</td>
<td>0.17</td>
</tr>
<tr>
<td>42</td>
<td>Cushing</td>
<td>4.21*</td>
<td>1.61*</td>
</tr>
<tr>
<td>43</td>
<td>von Hippel-Lindau</td>
<td>2.08</td>
<td>0.03</td>
</tr>
<tr>
<td>48</td>
<td>Multiple endocrine neoplasia</td>
<td>1.83</td>
<td>0.21</td>
</tr>
<tr>
<td>49</td>
<td>Multiple endocrine neoplasia</td>
<td>1.74</td>
<td>0.32</td>
</tr>
<tr>
<td>50</td>
<td>von Hippel-Lindau</td>
<td>2.43</td>
<td>0.04</td>
</tr>
<tr>
<td>Upper reference limit</td>
<td>3.00</td>
<td>0.54</td>
<td>0.66</td>
</tr>
</tbody>
</table>

* Denotes a concentration above the upper reference limits.
† Denotes a concentration more than threefold above the upper reference limits.

* "Metanephrines" refers to free normetanephrine and metanephrine. "Total metanephrines" refers to sulfomethylated and free normetanephrine and metanephrine. The sensitivity of (total) metanephrines for diagnosis of pheochromocytoma was calculated from patients with both a false-negative plasma (total) normetanephrine test result and a false-negative (total) metanephrine test result. The specificity of catecholamines was calculated from patients with both a false-negative plasma norepinephrine test result and a false-negative epinephrine test result. The specificity of metanephrines was calculated from patients with either a false-negative plasma (total) normetanephrine test result or a false-positive (total) metanephrine test result. The specificity of catecholamines was calculated from patients with either a false-positive plasma norepinephrine test result or a false-positive epinephrine test result.

**Table 4. Characteristics of Tests for Plasma Metanephrines and Catecholamines**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sensitivity (95% CI)</th>
<th>Specificity (95% CI)</th>
<th>Positive Predictive Value</th>
<th>Negative Predictive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metanephrines*</td>
<td>100 (52/52) (94 to 100)</td>
<td>85 (162/191) (79 to 90)</td>
<td>64 (52/81)</td>
<td>100 (162/162)</td>
</tr>
<tr>
<td>Total metanephrines</td>
<td>98 (42/43) (68 to 100)</td>
<td>82 (112/137) (74 to 88)</td>
<td>63 (42/67)</td>
<td>99 (112/113)</td>
</tr>
<tr>
<td>Catecholamines</td>
<td>85 (44/52) (72 to 93)</td>
<td>82 (156/191) (75 to 87)</td>
<td>56 (44/79)</td>
<td>95 (156/164)</td>
</tr>
</tbody>
</table>

* "Metanephrines" refers to free normetanephrine and metanephrine. "Total metanephrines" refers to sulfomethylated and free normetanephrine and metanephrine.
tests for plasma catecholamines decreased with increasing prevalence rates.

In terms of positive and negative predictive values, measurement of plasma concentrations of total normetanephrine and metanephrine provided no advantage over measurement of free metanephrine concentrations (Table 4). However, measurements of plasma concentrations of total metanephrines provided greater sensitivity for the diagnosis of pheochromocytoma than measurements of plasma concentrations of catecholamines.

**Discussion**

Because a pheochromocytoma secretes catecholamines directly into the circulation, any of several means to detect the tumor by assays of plasma or urinary catecholamines and their metabolites should theoretically prove adequate. However, the occurrence of false-nega-
The relation between pretest probability (that is, prevalence) and post-test probability shows the effect of prevalence of pheochromocytoma. Receiver-operating characteristic curves were constructed from estimates of the true-positive (sensitivity) and false-positive (1-specificity) rates obtained using upper reference limits determined from the mean plus 1, 1.5, 2.0, 2.5, 3.0, or 3.5 SDs. The different upper reference limits (nmol/L) for plasma catecholamines and metanephrines are tabulated below:

<table>
<thead>
<tr>
<th>Catecholamines</th>
<th>Metanephrines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norepinephrine</td>
<td>Epinephrine</td>
</tr>
<tr>
<td>1.0 SD</td>
<td>1.93</td>
</tr>
<tr>
<td>1.5 SD</td>
<td>2.41</td>
</tr>
<tr>
<td>2.0 SD</td>
<td>3.00</td>
</tr>
<tr>
<td>2.5 SD</td>
<td>3.75</td>
</tr>
<tr>
<td>3.0 SD</td>
<td>4.66</td>
</tr>
<tr>
<td>3.5 SD</td>
<td>5.85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Norepinephrine</th>
<th>Epinephrine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 SD</td>
<td>0.24</td>
</tr>
<tr>
<td>1.5 SD</td>
<td>0.36</td>
</tr>
<tr>
<td>2.0 SD</td>
<td>0.54</td>
</tr>
<tr>
<td>2.5 SD</td>
<td>0.79</td>
</tr>
<tr>
<td>3.0 SD</td>
<td>1.18</td>
</tr>
<tr>
<td>3.5 SD</td>
<td>1.76</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Normetanephrine</th>
<th>Metanephrine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norepinephrine</td>
<td>Epinephrine</td>
</tr>
<tr>
<td>0.43</td>
<td>0.66</td>
</tr>
<tr>
<td>0.53</td>
<td>0.84</td>
</tr>
<tr>
<td>0.66</td>
<td>1.05</td>
</tr>
<tr>
<td>0.84</td>
<td>1.32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Norepinephrine</th>
<th>Epinephrine</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.21</td>
<td>0.30</td>
</tr>
<tr>
<td>0.25</td>
<td>0.37</td>
</tr>
<tr>
<td>0.44</td>
<td>0.54</td>
</tr>
</tbody>
</table>

The negative predictive value of normal plasma concentrations of metanephrines was superior to that of normal plasma catecholamines regardless of prevalence rates (Figure 3, bottom), a disparity that increased with increasing prevalence. Even at the highest prevalence rates, normal plasma concentrations of metanephrines almost exclude diagnosis of pheochromocytoma. This means that in a general practice setting or in patients in whom pheochromocytoma is strongly suspected (for example, patients at a referral center who have hypertension, headache, and adrenal mass), normal plasma concentrations of metanephrines may exclude the diagnosis of pheochromocytoma.
concentrations. It is the free, not the conjugated, meta-
patients must be explanation is that the assay technique used (23) is a
In conclusion, normal plasma concentrations of meta-
were considered in that shirlv W<> fniinrl that inr.nciire- Internal Mcdicinc' Department of Internal Medicine, St. Radboud Uni-
108 15 July 1995 • Annals of Internal Medicine • Volume 123 • Number 2
pear to be actively metabolizing catecholamines to meta- nephrines for the diagnosis of pheochromocytoma. Thus, even when pheochromocytomas are do not. Tests for plasma metanephrines are more sensi-
rines had no advantage over measurement of free (unconjugated) metanephrines. Rather, the presence of a tumor causes relatively larger increases in free normeta-
nephines than in total metanephrine concentrations. It is the free, not the conjugated, meta-
phines that are produced within chromaffin tissue (unpublished observations). Thus, although plasma concentra-
tions of total metanephrines are technically easier to measure than plasma concentrations of free metanephrines, the latter yield superior results.
Consistent with findings in previous studies (2, 11), measurement of urinary metanephrines yielded false-nega-
tive results in a few patients. Why would a test for urinary metanephrines be less sensitive than a test for plasma concentrations of the same compounds? One expla-
ation is that a small percentage of patients in any large-scale study would be expected to provide an incomplete urine collection; this would yield false-negative re-
results. However, the normal creatinine excretion in the patients with false-negative results of tests for urinary metanephrines rules out this explanation. Another possible expla-
nation is that the assay technique used (23) is a colorimetric method. An assay for urinary metanephrines that uses the high-performance liquid chromatography

A limitation of our study is the lack of a reference group of patients with a panic disorder syndrome; a dia-
gnosis of pheochromocytoma in these patients must sometimes be excluded (28). Stress-induced elevations of plasma catecholamines in these patients may present a diagno-
Care. Because mild mental stress causes little change in plasma concentrations of metanephrines despite significant increases in plasma catecholamine concen-
trations (18), measurements of plasma concentrations of metanephrines may be particularly useful for excluding pheochromocytoma in patients with a panic disorder.
Greater and more consistent tumor-associated increases in plasma concentrations of metanephrines than in cate-
cholamine concentrations explain the better sensitivity of the test for the former for diagnosing pheochromocytoma. Intravenous infusion of catecholamines results in in-
creases in plasma concentrations of metanephrines that are less than 6% of those of the precursor amines (18). Thus, metabolism of catecholamines after they are re-
leased by a tumor into the circulation is not responsible for the greater and more consistent increases in plasma concentra-
tions of metanephrines compared with those in catecholamine concentrations in patients with a pheochro-

omocytoma. The production of 90% of plasma metaneph-

rine and as much as 40% of plasma normetanephrine from metabolism of catecholamines within the adrenal glands (18, 29) suggests that metanephrines are produced
within the tumor itself. This conclusion is supported by observations of high tumor-tissue concentrations of meta-
ephrines (30, 31) and high plasma normetanephrine concen-
trations in the venous effluent of pheochromocytomas (32). The conclusion is also supported by our findings
reported here and elsewhere (33) that tumor size is a
determinant of metabolite production but not of catechol-
amine release. Thus, even when pheochromocytomas are
diagnosis of pheochromocytoma, and normal plasma catecholamines or urinary metanephrines do not. Tests for plasma metanephrines are more sensi-
tive than tests for plasma catecholamines or urinary meta-
phines for the diagnosis of pheochromocytoma.

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References


