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New vistas in neurosurgery: A look to the horizon

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The association between cortisol dynamics and the course of aneurysmal subarachnoid hemorrhage

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ABSTRACT

Context: One of aneurysmal subarachnoid hemorrhage complication is delayed ischemic neurological deficits (DIND). It is postulated that cortisol dynamics might be associated with the severity of this complication.

Aims: The goal of the study is to investigate whether the peak of morning serum cortisol levels are associated with the severity of its complication during the course of the disease.

Settings and Design: This is a prospective cohort study conducted from January 2009 to June 2011, at our institution.

Materials and Methods: The study follows a consecutive cohort of patients for 14 days after the aneurysmal subarachnoid hemorrhage. Serum cortisol, cortisol binding globulin, adrenocorticotropic hormone (ACTH) were measured pre operatively and then on post operative days (POD) 2, 4, 7, and 10. Blood was drawn to coincide with peak cortisol levels between 08.00-09.00 hours. Neurological examinations were conducted at least twice daily and patient outcome were graded according to modified Ranklin Scale. DIND was defined by a decrease in the Glasgow Coma Scale of two or more points compared to the status on POD 1.

Statistical Analysis Used: All the results were analyzed using statistical software, Statistical Package for Social Sciences (SPSS v61; SPSS, Inc., Chicago, IL). Logistic regression analysis was used to compare the relationship between the variables.

Results: Thirty six consecutive patients are collected, but only 28 patients (12 M and 16 F) were eligible for the cohort analysis. Average patient age is 50.75 years old (50.75 ± 12.27), and more than 50% (15/28) arrived with World Federation of Neurologic Surgeons grade 3 or better. Elevated total cortisol levels of more than 24 μg/dl on day 2, 4, and 10 were associated with DIND, and the most significant being on day 4 (P=0.011). These patients also had a higher grade on the modified Ranklin scale of disability.

Conclusions: This study shows that the elevated levels of morning total cortisol in the serum are associated with the onset of DIND during the disease course, and it's also associated with bad outcomes.

Key words: Aneurismal subarachnoid hemorrhage, clipping, cortisol, delayed ischemic neurological deficits, outcome

Introduction

The cortisol dynamics might be associated with the severity and outcome after aneurysmal subarachnoid hemorrhage. It is well known that the cortisol plays an important role as a defense mechanism for stress conditions such as sepsis, fasting, trauma, pain, and tissue ischemic. Aneurysmal subarachnoid hemorrhage is a devastating condition which produces severe headache, constitutional symptoms, and neurological deficits. All of those things will precipitate a strong stress response and increase the serum cortisol levels through hypothalamic and autonomic nervous system pathways. Theoretically, cortisol itself may increase the risk of vasospasm through
its up-regulating endothelin-1 (vasoconstriction) and its
down-regulating nitric oxide (vasodilatation). Vasospasm has
been studied extensively and is a well recognized condition
following aneurysmal subarachnoid hemorrhage. It is a
major determinant of patient outcome even with appropriate
treatment, and clinically it is recognized as delayed ischemic
neurological deficits (DIND). The purpose of the study is to
investigate whether the morning serum cortisol level could
be associated with changes in the disease course.

Materials and Methods

Thirty-six consecutive patients (age > 18 years), with aneurysmal
subarachnoid hemorrhage, who underwent craniotomy clipping
procedure within the first two days of bleed, were included
in this study. Exclusion criteria were pregnancy, pre-existing
pituitary insufficiency, and glucocorticoid medication during
admission or treatment. This is a prospective cohort study
that follows the patients for the first two weeks after surgery.
All patients or their next of kin provided consent for this
study, which is approved by the Institutional Review Board
of Universitas Hasanuddin Makassar. A ten cc sample of
venous blood was taken pre-operatively, then every morning
(08:00-09:00 hrs) on POD 2, 4, 7, and 10. Serum cortisol, cortisol
binding globulin (CBG), and adrenocorticotropic hormone
(ACTH) were measured. Daily clinical assessments were done
by the investigator and another independent clinician.

All patients were managed in the intensive care unit by
the neurosurgeons and neurointensivists teams. Nimodipine was
routinely given for at least 14 days (2 mg/h). DIND is defined
as a decrease in the Glasgow Coma scale (GCS) of two or more
points compared to the GCS on POD 1. Patients who died on
POD 1 or suffered from severe complication of infection, heart
problem, kidney failure, sepsis, or multiple organ failure were
removed from the study.

The total serum cortisol levels were measured by immunoassay
(electrochemiluminescence immunoassay 'ECLA') using
Elecsys cortisol kit (cat no. 1167511 123); serum CBG levels
were measured by radioimmunoassay using CBG (transcortin)
RIA (cat no M13061) (IBI International GmbH, Hamburg,
Germany; reference value men 22-55 µg/ml; reference value
women 40-154 µg/ml); and serum ACTH measured using
ACTH ELISA (cat no ACD181) (Calbiotech Inc., Spring Valley, CA;
reference value: 8.3-57.8 pg/ml). Coolsen equation[29] was used to
calculate the amount of free cortisol in the serum. The patient
clinical condition and imaging were graded according to World
Federation of Neurologic Surgeons (WFNS) grading[30] and Fisher
grading.[31] Patients outcome was graded according to modified
Rankin scale.[32]

All the data were analyzed using statistical software, Statistical
Package for Social Sciences (SPSS v61; SPSS, Inc., Chicago, IL)
and reviewed by a professional statistical consultant. Due
to the sample size (n = 28), non-parametric statistics were
used for calculation. To assess whether cortisol variables are
distributed normally, we use Shapiro-Wilk test. Data were
presented descriptively and underwent univariate analysis.
Logistic regression bivariate analysis was used to see the
relationship between the total cortisol or free cortisol, and the
DIND neurological status. Regression bivariate analysis was
used to see the relationship between total cortisol and ACTH.
Logistic regression multivariate analysis was used to define
the interaction between the variables and DIND.

Results

There are 36 patients collected in this study, but eight patients
were withdrawn from analysis because of co-morbid condition
or inability to get follow-up data. The analysis cohort was
28 patients (12 M and 16 F). Patients average age is 50.75 years
old (50.75 ± 12.27) with the median age of 50.50 years old.
The duration of ICU stay in this study was 8-45 days (mean 23 days).
Average hospital stay was 32 days (11-69). Overall 59% (15/28)
of the patients arrived with WFNS grade 3, 35% (10/28) grade 2, and
10% (3/28) with grade 4. Blood distribution on initial computed
tomography (CT) scans showed the majority of cases (62.5%) with
Fisher grade 3; 25% with Fisher grade 2; and 12.5% with grade 4.

The most common location of aneurysm in this study is anterior
communicating artery (10) followed by posterior communicating artery (5), middle cerebral artery (4), internal
carotid (IC) artery bifurcation (4), IC-choroidal artery (2),
IC-ophthalmic artery (1), vertebral artery (1), and posterior
inferior cerebellar artery (1). Patient outcomes based on
modified Rankin Scale grading were fairly good. One patient died on
day 16, due to pneumonia.

The basal serum cortisol, on admission (before surgery),
ranged between 0.02 to 63.44 (mean 24.69 and median
22.49). The ACTH level represents the function of the
hypothalamo-pituitary-adrenal axis, whether it is solely related
to baseline cortisol levels or involving extra ACTH cortisol release
from the hemorrhage will be analyzed, periodically. Results of
cortisol, ACTH, CBG, and free cortisol are presented in [Table 1].

Statistically, total cortisol level on day 2, 4, and 10 shows
significant relationship with the clinical worsening
(DIND) [Table 2]. It is most significant on day 4 (P=0.011).
Unfortunately, the free cortisol levels did not show
proportional relationship with the DIND (P>0.083). The
increase total cortisol level is followed by the increased level
of CBG. This might be a body compensation to reduce
the biological effect of the cortisol. So, in other words, it's not
the biological effect of free cortisol that causes the clinical
worsening.

One case in our series, a young female 22-year-old. GCS 13
after surgery, and total cortisol level 37.23 µg/dl on day 4:
Table 1: Cortisol dynamics following microsurgical aneurismal clipping

<table>
<thead>
<tr>
<th>Day 0</th>
<th>Day 2</th>
<th>Day 4</th>
<th>Day 7</th>
<th>Day 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTH</td>
<td>n=24</td>
<td>n=17</td>
<td>n=18</td>
<td>n=20</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>29.44 (24.90)</td>
<td>25.89 (23.14)</td>
<td>25.94 (21.50)</td>
<td>32.42 (28.23)</td>
</tr>
<tr>
<td>Median</td>
<td>9.73</td>
<td>14.80</td>
<td>13.53</td>
<td>19.75</td>
</tr>
<tr>
<td>Min</td>
<td>0.46</td>
<td>0.93</td>
<td>0.46</td>
<td>4.46</td>
</tr>
<tr>
<td>Max</td>
<td>295.82</td>
<td>250.65</td>
<td>212.70</td>
<td>89.47</td>
</tr>
<tr>
<td>Cortisol</td>
<td>n=28</td>
<td>n=27</td>
<td>n=28</td>
<td>n=28</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>26.69 (16.95)</td>
<td>28.22 (12.12)</td>
<td>23.94 (10.40)</td>
<td>26.86 (12.02)</td>
</tr>
<tr>
<td>Median</td>
<td>22.19</td>
<td>27.18</td>
<td>22.55</td>
<td>21.43</td>
</tr>
<tr>
<td>Min</td>
<td>0.02</td>
<td>12.10</td>
<td>2.53</td>
<td>6.16</td>
</tr>
<tr>
<td>Max</td>
<td>63.44</td>
<td>63.60</td>
<td>48.73</td>
<td>63.44</td>
</tr>
<tr>
<td>Free-Cortisol</td>
<td>n=21</td>
<td>n=22</td>
<td>n=23</td>
<td>n=23</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>1.80 (0.18)</td>
<td>1.54 (0.91)</td>
<td>1.11 (0.91)</td>
<td>1.18 (1.90)</td>
</tr>
<tr>
<td>Median</td>
<td>1.72</td>
<td>1.34</td>
<td>0.93</td>
<td>1.10</td>
</tr>
<tr>
<td>Min</td>
<td>0.10</td>
<td>0.43</td>
<td>0.11</td>
<td>0.19</td>
</tr>
<tr>
<td>Max</td>
<td>3.66</td>
<td>4.25</td>
<td>3.99</td>
<td>9.04</td>
</tr>
<tr>
<td>CBG</td>
<td>n=24</td>
<td>n=17</td>
<td>n=27</td>
<td>n=28</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>25.06 (20.72)</td>
<td>37.50 (15.97)</td>
<td>37.52 (12.44)</td>
<td>40.96 (15.30)</td>
</tr>
<tr>
<td>Median</td>
<td>20.78</td>
<td>28.15</td>
<td>36.00</td>
<td>40.63</td>
</tr>
<tr>
<td>Min</td>
<td>10.75</td>
<td>12.50</td>
<td>10.75</td>
<td>5.00</td>
</tr>
<tr>
<td>Max</td>
<td>54.50</td>
<td>79.75</td>
<td>63.00</td>
<td>72.75</td>
</tr>
</tbody>
</table>

ACTH - Adrenocorticotropic hormone

63.44 µg/dl on day 7, was release from ICU care, on day 9, to the ordinary ward. She was perfectly well (GCS 15), fully oriented, since POD 1 to 9, but she still suffered from significant headache. Unfortunately, on the evening POD 9, her conscious levels dropped to GCS 12, showing signs of lateralization, and finally we have to perform decompression craniectomy, just before the surgery, her GCS was 7 with one side pupil dilated. On the next day of the surgery (day 10), her total cortisol level was 50.02. She went through tracheostomie, stayed in ICU for more than one month, accounting for a total hospital stay of 67 days. She went home with lot of assistance, and finally, she recovered very well after three months. Patient with increased level of total cortisol (>24 µg/dl, especially within the first week), although have GCS 15 with only mild headache, should, probably, be kept in ICU or Neuro Step-down Unit (NSU).

The function of hypothalamo pituitary adrenal axis is the primary regulator for cortisol secretion. There is a linear relationship between ACTH and total cortisol release during the first week. ACTH levels continued to rise during the first week, and gradually decreased during the second week. Although the ACTH levels were decreasing in the second week, but the total cortisol levels were persistently high (Figure 1).

Discussion

There is an evidence showing that the cortisol dynamics might be associated with the severity and outcome after aneurysmal subarachnoid hemorrhage. although a previous study on the pituitary adrenal function in acute subarachnoid hemorrhage (SAH) has shown that the SAH severity does not affect cortisol concentration, that study did not describe the relationship between the total cortisol level and the patient's neurologic state. Also, they were unable to show any difference in the adrenal response between comatose (GCS<8) and non comatose patients. Vugouwen et al. have shown that the increase cortisol level is associated with the DIND, through hyperglycemia and endothelium dysfunction (von Willebrand factor). Whether the cortisol is just part of the stress process and is unrelated to the ongoing worsening of patient neurologic status, or it is contributing to make the patient worst, is still unclear. In our study, it shows that the total morning cortisol levels were associated with DIND on POD day 2, 4, and 10, and the most significant one is on POD 4 (P=0.011). It is consistent with the fact that most of symptomatic vasospasm (who presented with DIND) usually starts on day three and four, after SAH, and progressively gets worsened until the peak levels of oxy-hemoglobin at day seven, after the SAH.

Normally, the morning total cortisol level should not exceed 18 µg/dl. During the disease course, the cortisol could reach four times normal value (63.44 µg/dl). The increased level of total serum cortisol was followed by the increase of CBG. The end result was that the free cortisol which was the one that have biological role, does not increase. The increase level of CBG may represent the body compensation to control the biological effect of cortisol. More than 50% of cortisol itself is bound to cortisol binding globulin (CBG), and only unbound free cortisol is responsible for physiological effects. Our result shows that the free cortisol levels do not correlate with the DIND, during the follow-up. This evidence suggests that...
that the cortisol level is only part of the stress process and is not contributing to the clinical worsening of patient with DIND. Although, theoretically, cortisol itself could increase the risk of vasospasm through its up-regulating endothelin-1 (vasoconstriction) and its down-regulating nitric oxide (vasodilation). In our study, the CBG were increased proportionally following the total cortisol level, and this might explain why the free cortisols were maintained at a constant level. This supports the observation that although the total cortisol level is increased, but the biological consequences are not great.

Our study supports the evidence that the total morning cortisol level in serum is associated with the onset of DIND. The total cortisol levels frequently elevate within 24 hours prior to the clinical worsening (GCS decrease ≥2 points), and from our observation, the mild hypoxia usually make it worst (data not presented). It’s probably the ischemia at the level of endothelial
cells following the hypoxia that turn on the transcription of human endothelin-1 gene in chromosome 6.[13] The evidence suggests to consider the total cortisol level as one of the factors before releasing the patient from ICU care or NSU to the ordinary ward, especially during the first week after surgery. The patients with high total cortisol level that do not fit the criteria for DIND, very often will show increasing headache. We need to put attention for the increasing headache, since it could be a non-localizing finding associated with the early DIND.

Interestingly, three cases in our series with extremely low pre-operative total cortisol levels (<1 µg/dl), showed increase in cortisol level on the following days, but none of them developed DIND, despite the cortisol exceeding 24 µg/dl. In our study, low preoperative cortisol level was not associated with the clinical worsening (DIND). Elevation of cortisol level on the post-operative days suggests that the HPA response function is intact.

During the first few days of SAH, the cortisol level is totally dependent on the Hypothalamic - Pituitary-adrenocortical (HPA) function. The ACTH is released from the anterior pituitary to stimulate cortisol release from the adrenal gland. It is the major source of the cortisol, but on POD 7, the function is taken over by the extra ACTH cortisol release [Figure 1]. In the second week, although the ACTH level is decreasing, the total cortisol levels are persistently high. It supports the evidence that there is an extra ACTH cortisol release. Interleukin 6 (IL-6) constitutes a potentially important factor of extra-ACTH cortisol release,[16] besides IL-1 and tumor necrosis factor-alpha.[15] The role of inflammatory pathway becomes substantial in the second week.

Total cortisol level also correlates with the modified Rankin scale. Patients with total cortisol levels >24 µg/dl are shown to have higher grade of modified Rankin scale. In long term follow-up (>12 months), their grade is likely to improve.

Conclusion

This study shows that the elevated levels of morning total cortisol in the serum are associated with the onset of DIND during the disease course, and it’s also associated with bad outcomes.

References