Abstract

Objective: Raised plasma levels of procalcitonin (proCT) represent an early marker for septicemia. They are related to disease severity and inversely to outcome and response to treatment. ProCT is presumably synthesised in tissues other than the thyroid C-cells which are the source of calcitonin (CT) in normal physiology. This study compares proCT and its cleavage products in the serum of patients with septicaemia with those in medullary thyroid carcinoma (MTC).

Methods: Immunoreactive proCT and its cleavage products were extracted from the serum of patients with septicaemia or MTC using octadecylsilyl silica columns and characterised by reversed phase HPLC and Western blot analysis. ProCT, CT(1–32) and the flanking peptides PAS-57 and PDN-21 were recognised with antibodies specific for the individual peptides.

Results: ProCT and a 10 kDa polypeptide were recognised with antibodies to PAS-57, CT(1–32) and PDN-21. An 8 kDa proCT fragment was detected with antibodies to CT and PDN-21. However, intact CT(1–32), PAS-57 and PDN-21, found in the serum of MTC patients, were undetectable. The results indicate partial cleavage of proCT in septicaemia different from that in MTC patients.

Conclusions: ProCT and 10 and 8 kDa proCT fragments were recognised in the circulation of septic patients. They were different from the known proCT-processing products PAS-57, CT(1–32) and PDN-21 identified in the serum of normal subjects and of MTC patients. Distinct cleavage of proCT may contribute to the symptoms of septicaemia.

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weight of proCT in septicaemia was smaller than that in MTC patients. Ten and eight kDa proCT fragments were recognised in the serum of septic patients. They were different from the classical proCT processing products PAS-57, CT(1–32) and PDN-21 identified in MTC patients and normal subjects.

**Subjects and methods**

**Subjects**

Patients with septicaemia and with MTC have been investigated. Two female and seven male patients fulfilled the criteria of a systemic inflammatory response syndrome. Eight of the nine patients had positive bacterial blood cultures. Two female and two male patients presented histologically verified MTC. The clinical data of all the patients are summarised in Table 1. The collection of blood samples from septic patients was approved by the Ethical Committee of the University of Ulm (Germany), whereas the collection of the serum from MTC patients for diagnostic purposes predated the establishment of an Ethical Committee of the Zurich University Hospitals (Switzerland).

**Materials**

Salmon (s) CT was donated by S Guttmann and human (h) CT and PAS-57 by H Rink (Novartis, Basel, Switzerland). Human α-calcitonin gene-related peptide (αCGRP) was purchased from Bachem (Bubendorf, Switzerland) and the carboxyl-terminal cleavage peptide of proCT (PDN-21) from Peninsula Laboratories, Inc. (Belmont, CA, USA). Acetonitrile, heptafluorobutyric acid and β-mercaptoethanol were obtained from Fluka Chemic AG (Buchs, Switzerland). Other chemicals and reagents were purchased from Sigma Chemicals Co. (St Louis, MO, USA) and E Merck (Darmstadt, Germany) at the best purity available.

**Imunoassays**

Serum levels of proCT were measured in a bioluminescence immunoassay (B.R.A.H.M.S.; Diagnostica, Berlin, Germany) according to the manufacturer’s instructions. Immunoreactive CT in serum and HPLC fractions, and PAS-57 and PDN-21 in HPLC fractions were identified by homologous and specific radioimmunoassays (RIA) in several dilutions as previously described (11, 12).

**Peptide extraction**

Serum samples collected from septic and MTC patients were kept frozen at −20°C until used. The samples of individual MTC patients collected on different days were pooled prior to peptide extraction. The serum samples were then diluted with equal volumes of 0.1% trifluoroacetic acid and kept for 30 min at room temperature. Subsequently, they were cleared by centrifugation at 10 000 g at 4°C for 10 min. The supernatants were applied to Sep-Pak C18 cartridges (Waters Associates, Milford, MA, USA) activated with 10 ml methanol and equilibrated with 10 ml 0.1% trifluoroacetic acid. The cartridges were washed with 10 ml 0.1% trifluoroacetic acid and the peptides eluted with 3 ml 80% acetonitrile in 0.1% trifluoroacetic acid. The extracts were lyophilised and redissolved in 1 ml 0.1 M acetic acid for further analysis. The overall recovery of trace amounts of [125I]sCT added to individual serum samples prior to the extractions was 85.5±7.5% (means±S.D.).

<table>
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<tr>
<th>Patient</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Body temperature (°C)</th>
<th>C-reactive protein (mg/l)</th>
<th>Leukocytes (10⁹/l)</th>
<th>Blood culture</th>
<th>Calcium (mmol/l)</th>
<th>ProCT (ng eq/ml)</th>
<th>CT (ng eq/ml)</th>
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n.d. = not done. Normal range: C-reactive protein <5 mg/l; leukocytes 5–10 × 10⁹/l; calcium 2.2–2.6 mmol/l; ProCT <0.5 ng eq/ml; CT <0.05 ng eq/ml.
**HPLC analysis**

Serum extracts were subjected to reversed phase HPLC as described (12). Trace amounts of \([^{125}\text{I}]\text{sCT}\) and \([^{125}\text{I}]\text{h\alphaCGRP}\), not interfering in the RIA, were used for calibration of retention times in individual chromatograms. Fractions (1 ml) were collected for analysis by RIA. Aliquots (100 μl) of the individual fractions were lyophilised in the presence of 100 μl charcoal-treated serum and reconstituted in 1 ml RIA buffer. Fractions analysed on Western blots were lyophilised and reconstituted and kept at 95°C for 5 min in 10 μl protein gel loading buffer.

**Western blot analysis**

Proteins in HPLC fractions were separated by SDS-PAGE and electro-transferred at 25 V and 4°C overnight to Hybond ECL nitrocellulose membranes in a Trans-Blot cell (BioRad Laboratories, Richmond, CA, USA). Kaledoscope polypeptide size markers (3.5 – 37.6 kDa; BioRad Laboratories) were used.

Immunoblots were blocked with 10% low-fat milk in 20 mM Tris–HCl, pH 7.6, 137 mM NaCl (TBS) at room temperature for 1 h and washed five times for 10 min with TBS containing 0.1% Tween 20. Immunoreactive PAS-57 and CT components were sequentially visualised by enhanced chemiluminescence (ECL) with goat antibodies to synthetic PAS-57 (1:1000) (12) and secondary horseradish peroxidase (HRP)-labelled mouse antibodies to goat immunoglobulins (1:10 000) (Amersham Bioscience, Little Chalfont, Bucks, UK), and with rabbit antibodies to CT (1:1000) (Chemicon, Temecula, CA, USA) and secondary biotin-labelled antibodies to rabbit immunoglobulins (1:10 000) and HRP-labelled streptavidin (Amersham Bioscience). The blots were exposed to X-ray films at room temperature for 1 h in the presence of ECL Western blotting detection reagent (Amersham Bioscience). Antibodies to PAS-57 were removed from filters by incubation on a horizontal shaker in 100 mM β-mercaptoethanol, 2% SDS, 6.25 mM Tris–HCl, pH 6.7, at 50°C for 30 min. Protein immunostaining with preimmune serum from goats was considered as non-specific.

X-ray films were scanned with a high resolution digital camera (PIXERA, Los Gatos, CA, USA) and non-specifically stained proteins on digital images were subtracted by computer-based inverse overlay of specific and non-specific images.

**Results**

Immunoreactive proCT and CT in the serum of septic patients ranged from 2.4 to 54.3 ng eq/ml and from 1.5 to 4.9 ng eq/ml respectively (Table 1). In the serum of MTC patients, CT levels varied between 3.9 and 187.0 ng eq/ml.

![Figure 1](https://www.eje.org) Representative reversed phase HPLC profiles of immunoreactive CT (A), PDN-21 (B) and PAS-57 (C) in extracts of 10 ml serum from septic (A) and MTC (B) patients. Serum from patients (six septic and eleven MTC) (Table 1) was extracted as described in Subjects and methods. Columns of Nucleosil 100-7C18 (Waters, Milford, MA, USA) were eluted with a gradient of acetonitrile and heptfluorobutyric acid (broken line). Elution positions of synthetic PDN-21 (I), hCT (II) and PAS-57 (V) and of \([^{125}\text{I}]\text{sCT}\) (III) and \([^{125}\text{I}]\text{h\alphaCGRP}\) (IV) are indicated by arrows.
In serum extracts of patients with MTC, predominant forms of immunoreactive CT and PAS-57 had the retention times and sizes of synthetic CT(1–32) and PAS-57 (Figs 1B and 2C and D). A PDN-21 component, eluting on HPLC with the retention time of synthetic PDN-21 was only recognised by antibodies to the peptide (Fig. 1B). A CT/PDN-21 immunoreactive polypeptide with a retention time of 58 min and a size slightly smaller than 6 kDa (fractions 60–62; Fig. 2C) was separated from the individual mature peptides (Fig. 1B). Another predominant polypeptide recognised by antibodies to PAS-57, CT(1–32) and PDN-21 eluted between 69 and 76 min and had the size of proCT (Figs 1B and 2C and D). A co-eluting 10 kDa polypeptide recognised with antibodies to CT and PAS-57 remains to be identified.

Taken together, CT, PDN-21 and PAS-57 components in serum extracts of septic and MTC patients differed in retention times on HPLC and in size on Western blot analysis. In septic patients, proCT was not cleaved into the classical processing products CT(1–32), PDN-21 and PAS-57 identified in the serum of MTC patients.

Discussion

ProCT(3–116), rather than intact proCT, has been identified as the predominant protein product of the CT gene in the circulation of patients with septicaemia (15, 16). In the present study, major circulating cleavage products of proCT in septic patients were characterised by combined HPLC and Western blot analysis and compared with proCT processing products recognised in the serum of MTC patients (Fig. 3).

ProCT of approximately 12 kDa in serum extracts of septic patients was confirmed to be slightly smaller in size than that observed in MTC patients. It likely represents proCT(3–116) identified by Weglöchner et al. (15). Here, two novel 10 and 8 kDa proCT fragments have been identified with antibodies to CT(1–32) and PDN-21 as predominant components in the circulation of septic patients. The 10 kDa proCT fragment was also recognised with a PAS-57 antiserum. Proteolytic cleavage of proCT(3–116) into this 10 kDa fragment presumably occurred through N-terminal truncation, leaving the PAS-57 epitope intact. The 8 kDa polypeptide was not recognised by antibodies to PAS-57, but was larger than a 6 kDa proCT fragment observed in MTC patients that likely consisted of CT and PDN-21. The cleavage therefore occurred within the N-terminal PAS-57 sequence of proCT thereby removing the PAS-57 epitope. Additional proteolytic truncation in the C-terminal PDN-21 portion of the 10 and 8 kDa proCT fragments, leaving the epitope recognised by the PDN-21 antibodies intact, cannot be ruled out. With the 10 and 8 kDa proCT fragments identified here it seems unlikely that the processing of proCT in septic patients is that observed in MTC patients and in normal subjects as implied by Snider et al. (10).

In conclusion, proCT(3–116) and 10 and 8 kDa proteolytic cleavage products in the circulation of septic patients, different from CT(1–32), PAS-57 and PDN-21 identified in normal subjects and in MTC patients, may contribute to the symptoms of septicaemia.
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References


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