Selective Venous Blood Sampling for Hyperparathyroidism with unclear Localization of the Parathyroid Gland

Selektives Venenblutsampling bei Hyperparathyreoidismus mit unklarer Nebenschilddrüsenlokalisation

Abstract

**Purpose:** Evaluation of the benefit of selective venous blood sampling (SVS) for the pre-operative identification of parathyroid adenomas with unclear localization in non-invasive diagnostics.

**Materials and Methods:** In a retrospective study, all patients (n = 23) with primary (n = 21) or tertiary (n = 2) hyperparathyroidism were evaluated from 2005 to 2016 at the Hospital Nuremberg-North. These patients all received one (n = 20) or more (n = 3) SVS. 15 patients had one or more previous unsuccessful surgeries (group A), 8 patients received the SVS primarily before the first surgery (group B). Results of SVS were compared with the results of surgery, non-invasive diagnostic procedures and clinical follow up.

**Results:** In 24 out of 26 SVS a significant PTH peak was found. 19 patients underwent surgery after SVS. In 16 of these cases (84%) the SVS peak was concordant with the intraoperative localization. Thus, SVS of all operated patients had a sensitivity of 94%. Considering only patients with prior HPT surgery the sensitivity was 89%. In none of the 26 examinations complications occurred.

**Conclusion:** Our results demonstrate that selective venous blood sampling SVS in cases with unclear imaging of parathyroid adenomas is an effective and low-risk invasive diagnostic method to localize parathyroid adenomas and helps to improve surgical therapy.

**Key points:**

- low risk invasive diagnostic procedure to localize parathyroid adenomas
- additional step if non-invasive diagnostics are negative or inconclusive
- high sensitivity in the detection of parathyroid adenomas
Hyptberthyroidism (HPT) is characterized by an increased produc-
tion of parathyroid hormone (PTH) by the parathyroid
glands. The excess secretion can be caused autonomously
(white or tertiary HPT) or can be regulatory in nature (sec-
tondary HPT). With an incidence of 1:1000 to 4:1000, primary
HPT is the most common cause of hypercalcemia in the out-
patient setting. Twice as many females are affected compared
to males [1]. Typical manifestations include generalized bone
disease, kidney stones and nephrocalcinosis, gastrointestinal,
cardiovascular, neuromuscular and neuropsychiatric symp-
toms. However, according to frequent screening of laboratory
studies, 85% of cases, a solitary adenoma is the cause; in 1
cases hyperplasia affects several or all parathyroid glands [2]
The only curative therapy is parathyroidectomy [3]. Although
bilateral neck exploration (BNE) is the traditional surgical
method and gold standard, due to improved localization diag-
nostics in recent decades, various minimally-invasive proce-
dures (MIP) have been established. The success rates are simi-
lar, > 95%; correspondingly the reoperation rate is approx.
5% [4–6]. The role of general preoperative localization diag-
nostics has been controversially discussed to date [7]. Thus in
the case of primary BNE, preoperative localization diagnost-
ics is not mandatory; however, it is obligatory when per-
foming a minimally-invasive parathyroidectomy, in cases of
reintervention as well as in cases of suspected ectopic adeno-
mas [7]. The established non-invasive imaging procedures
primarily include ultrasound (US) and Tc-99-m Sestamibi
scintigraphy (Tc99-m Mibi SZ). In addition, magnetic reso-
nance imaging (MRI) as well as computed tomography (CT)
are used in selected cases. However there are always situa-
tions in which non-invasive diagnostics provide no result or
contradictory results. This is particularly problematic for pa-
tients with previous surgery, since reoperation is accompa-
nied by an increased complication rate and a decreased suc-
cess rate compared to primary operations [6]. Adequate
preoperative localization diagnostics are therefore strongly
encouraged in order to allow the surgeon a targeted surgical
procedure [8]. In these cases, selective venous sampling (SVS)
represents a minimally-invasive diagnostic method that can
be indicative when localizing adenomas of the parathyroid
glands; however this technique is falling into disuse.

The aim of our study was to investigate the benefit of SVS for
patients with indistinct localization of adenomas of the para-
thyroid glands during non-invasive imaging prior to primary
surgery or reoperation and thus assess the value of SVS when
localizing parathyroid gland adenomas.

Materials and Methods

A retrospective analysis included all patients of the Nürnberg-
Nord Clinic (n = 23) who during the period 2005–2016
underwent one (n = 21) or more (n = 3) selective venous sam-
pling procedures. The mean age was 60 years (26 – 76 years);
61% of the patients were female and 39% were male. Of the
23 patients, 21 had primary HPT (91%) and 2 had tertiary
HPT (9%). The diagnoses were verified chemically in the
labouratory. Fifteen patients with persistent or recurrent
HPT received SVS prior to reoperation (Group A). Persistence
means that raised serum calcium values are measurable
within the first 6 months postoperatively. Recurrence is indi-
cated when serum calcium increases again after 6 months
of normal postoperative calcemia. Eight patients received
SVS for primary diagnosis prior to the first intervention
(Group B). Four members of this group had already under-
gone thyrody surgery. All patients first underwent non-inva-
sive localization diagnostics, initially always a Tc99m Mibi
SZ (n = 23) and/or an ultrasound (n = 17), supplemented by
an MRI (n = 8) or a CT (n = 10) (Fig. 1). Indication for SVS
was supported by at least two non-invasive diagnostic pro-
cedures due to missing or ambiguous localization of the
parathyroid glands.

The SVS was positive if a significant PTH peak could be
shown. This had to lie by a factor of 1.5 above a reference value
peripherally obtained during the SVS [9]. The sam-
ping site with the highest peak was then considered the
probably location of the hyperactive parathyroid gland.
A peak below the confluence of the two brachiocephalic
veins indicated an entopic location of the parathyroid gland
in the mediastinum.

An operation was considered successful if, in addition to
morphological assessment, the PTH value during intraop-
erative monitoring dropped by 50% of the initial value ap-
prox. 10 minutes after removal of the gland.

Intraoperative localization with a corresponding drop in PTH
during monitoring, in combination with final histological
confirmation was considered the gold standard for verifica-
tion of the SVS. Correspondingly the results of the SVS were
evaluated as follows: True-positive, if a significant PTH peak
existed, the anatomical location provided by SVS coincided
with the intraoperative location and the diagnosis was his-
tological confirmed. True-negative, if there was no signi-
ficant PTH peak, and no mass could be located during the
operation. False-positive, if there was a significant PTH peak,
but no adenoma could be found during the operation at the
relevant location. False-negative, if a mass could be found
during the operation, yet no suitably significant PTH peaks
could be shown by SVS. The data used for the study were ob-
tained from radiological findings, physician reports, labora-
ory and histological findings.

SVS Technique

Access is via puncture of the right femoral vein using the
Seldinger method and placement of a 5-F sheath. Depending
on vessel anatomy, the following catheter configurations
can be used: 4-F Cobra (Cordis®, C1, Tempo Aqua), vertebral
(MeritMedical®) or straight configuration (Terumo®). The
selective catheter is then navigated using a probing wire
(Terumo®, Angled 3 cm, normal or stiff) and sectional view
of the venous system using contrast fluoroscopy from cra-
nial to caudal for the following sampling positions: internal
jugular vein, both sides, each in the upper, middle and low-
er third of the thyroid gland, subclavian vein, both sides;
right brachiocephalic vein; left lateral and medial brachio-
cephalic vein; or in the region of the confluence of the inferior thyroid vein; superior vena cava; azygos vein, right atrium; inferior vena cava; renal vein, both sides. DSA series are needed only in exceptional cases, when the vessel anatomy is complex or if venous valves are difficult to pass through (● Fig. 2).

After each change of position 2 ml of blood are aspirated and discarded in order to ensure absolute separation of PTH values from the various sampling positions. This is followed by a second aspiration of 3 ml blood with a fresh syringe; the blood is sterilely injected into an EDTA tube. Immediately after filling, the tube is labeled and the blood sample is cooled. The individual hormone values are carried over to an anatomical diagram according to PTH determination, allowing association with a location (● Fig. 3). This supports the distinction between location on the left or right side of the neck at various levels and location in the mediastinum. It should be noted that due to the distance between the individual sampling locations and the retrograde blood flow, the location of the target may lie somewhat peripherally to the sampling site. Rare complications include smaller hematomas which may result from perforation of a vein by the guide wire or during an attempt to pass through a venous valve. Furthermore, there are known risks associated with contrast administration (renal insufficiency, thyrotoxic crisis, anaphylactic reaction).

**Results**

A significant PTH peak could be determined in 24 of the 26 SVS procedures (92%). No complications resulted from any of the 26 procedures. On average, 16 ± 3 samples were taken per examination.

Due to various reasons, 4 of the 23 patients could not undergo an operation (other comorbidities, refusal, etc.). After the SVS was performed, 19 patients were operated on, including 11 from Group A (with previous HPT surgery) and 8 from Group B (no previous HPT surgery). Based on intraoperative localization with a corresponding drop in PTH, in combination with final histological confirmation as the gold standard, the results of SVS could be verified as follows: true-positive 84% (16/19); true-negative 0% (0/19), false-positive 11% (2/19), false-negative 5% (1/19) (● Table 2). On the whole SVS had a positive predictive value (operated patients from Groups A+B) of 89% with a sensitivity of 94%. Considering the group of patients with prior HPT surgery alone, the positive predictive value was 80% with a sensitivity of 89% (● Table 3).

For the sake of completeness, the results of the non-invasive diagnosis of operated patients have been included. The criterion for the accuracy of the results of each method was analogous to the assessment of SVS: the indicated location in reference to the above-defined gold standard. Following are only the true-positive results: Tc99m Mibi SZ 16% (3/19), US 20% (3/15), CT 25% (2/8), MRI 38% (3/8). Targeted surgery was performed wherever a PTH peak was located. If there was a lateral peak, surgery was performed on one side (9/19); mediastinal surgery (4/19) was performed if a peak
was below the confluence of both brachiocephalic veins. Bilateral exploration was only performed if there was a significant bilateral peak (1/18) or there was a peak in the region of the inferior thyroid vein (3/19). In the latter case, however, only the caudal parathyroid gland was explored. Further exploration occurred if no adenoma could be found after an initial targeted procedure (2/19). In total, 18 of the 19 patients (95%) could be successfully operated on. The following histological results were observed: solitary adenoma (13/18), 2 adenomas (1/18), one or more hyperplasias (3/18), hyperplasia and adenoma (1/18). Table 1 presents the results of SVS and surgery for all patients, with indication of the PTH peak, systemic preoperative PTH and PTH value approx. 10 minutes after excision of the parathyroid adenoma. As expected, the 2 patients with tertiary HPT (tHPT) exhibited a higher systemic PTH level compared to the patients with primary HPT (pHPT).

Discussion

The aim of the study was to investigate the benefit of SVS among patients with indistinct parathyroid glands location using non-invasive diagnosis. Of the SVS procedures performed, 92% exhibited a significant PTH peak; in 84% of the operated patients SVS was consistent with the location discovered surgically. Sensitivity of all operated patients was 94%. A sensitivity of 89% was demonstrated for the cohort of patients who had been previously treated surgically with persistent/recurrent HPT. Several procedures are available to localize parathyroid adenomas; they vary with respect to their value, invasiveness and cost. Ultrasound represents the most widely available and cost-effective examination method but is heavily dependent on the experience of the examiner, the size and position of the parathyroid gland. Depending on the publi-
The sensitivity of US in detecting a pathological parathyroid gland lies between 70–90% [10]. Among patients with persistent or recurrent HPT, sensitivity is reduced to 36–63% [11]. False-positive diagnoses are often the result of the difficulty in differentiating between parathyroid glands and thyroid nodes, lymph nodes, prominent blood vessels or muscles. False-negative results can be caused by tiny adenomas or ectopic position in sonographically inaccessible (e.g. mediastinal) areas [12]. An additional frequently employed examination method is 99mTc-Sestamibi scintigraphy. In addition to planar images, using either dual phase or subtraction in combination with a second radionuclide such as Iodine-123, there is also the possibility of 3-dimensional imaging using SPECT (single photon emission computed tomography). Sensitivity of 99mTc-Mibi SZ lies between 54–96%; most studies average around 80% [13]. Analogous to US, thyroid nodes or lymph nodes as well as brown adipose tissue can result in false-positive results; very small adenomas can lead to false-negative diagnoses [14]. Imaging methods such as CT and MRI have a secondary utility in locating pathological parathyroid glands. These methods are primarily used in cases of unclear findings resulting from the above-mentioned established procedures, but with limited success. Compared to US, thyroid nodes or lymph nodes as well as brown adipose tissue can result in false-positive results; very small adenomas can lead to false-negative diagnoses [14]. Imaging methods such as CT and MRI have a secondary utility in locating pathological parathyroid glands. These methods are primarily used in cases of unclear findings resulting from the above-mentioned established procedures, but with limited success. Compared to US, thyroid nodes or lymph nodes as well as brown adipose tissue can result in false-positive results; very small adenomas can lead to false-negative diagnoses [14]. Imaging methods such as CT and MRI have a secondary utility in locating pathological parathyroid glands. These methods are primarily used in cases of unclear findings resulting from the above-mentioned established procedures, but with limited success. Compared to US, thyroid nodes or lymph nodes as well as brown adipose tissue can result in false-positive results; very small adenomas can lead to false-negative diagnoses [14]. Imaging methods such as CT and MRI have a secondary utility in locating pathological parathyroid glands. These methods are primarily used in cases of unclear findings resulting from the above-mentioned established procedures, but with limited success. Compared to US, thyroid nodes or lymph nodes as well as brown adipose tissue can result in false-positive results; very small adenomas can lead to false-negative diagnoses [14]. Imaging methods such as CT and MRI have a secondary utility in locating pathological parathyroid glands. These methods are primarily used in cases of unclear findings resulting from the above-mentioned established procedures, but with limited success. Compared to US, thyroid nodes or lymph nodes as well as brown adipose tissue can result in false-positive results; very small adenomas can lead to false-negative diagnoses [14]. Imaging methods such as CT and MRI have a secondary utility in locating pathological parathyroid glands. These methods are primarily used in cases of unclear findings resulting from the above-mentioned established procedures, but with limited success. Compared to US, thyroid nodes or lymph nodes as well as brown adipose tissue can result in false-positive results; very small adenomas can lead to false-negative diagnoses [14]. Imaging methods such as CT and MRI have a secondary utility in locating pathological parathyroid glands. These methods are primarily used in cases of unclear findings resulting from the above-mentioned established procedures, but with limited success. Compared to US, thyroid nodes or lymph nodes as well as brown adipose tissue can result in false-positive results; very small adenomas can lead to false-negative diagnoses [14]. Imaging methods such as CT and MRI have a secondary utility in locating pathological parathyroid glands. These methods are primarily used in cases of unclear findings resulting from the above-mentioned established procedures, but with limited success. Compared to US, thyroid nodes or lymph nodes as well as brown adipose tissue can result in false-positive results; very small adenomas can lead to false-negative diagnoses [14]. Imaging methods such as CT and MRI have a secondary utility in locating pathological parathyroid glands. These methods are primarily used in cases of unclear findings resulting from the above-mentioned established procedures, but with limited success. Compared to US, thyroid nodes or lymph nodes as well as brown adipose tissue can result in false-positive results; very small adenomas can lead to false-negative diagnoses [14].

<table>
<thead>
<tr>
<th>patient</th>
<th>SVS correct</th>
<th>PTH peak in SVS [pg/ml]</th>
<th>PTH systemic preoperative [pg/ml]</th>
<th>PTH intraoperative approx. 10 min post-excision [pg/ml]</th>
<th>surgery concordant</th>
<th>prior surgery, result of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. + 1146</td>
<td>134</td>
<td>34</td>
<td>+</td>
<td>thyroid surgery, successful operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. + 278</td>
<td>67</td>
<td>19</td>
<td>+</td>
<td>thyroid OP, successful operation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. – 97</td>
<td>84</td>
<td>14</td>
<td>+</td>
<td>pHPT OP, successful reoperation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. + 1298</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. + 350</td>
<td>119</td>
<td>34</td>
<td>+</td>
<td>pHPT OP, successful reoperation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. + 648</td>
<td>113</td>
<td>20</td>
<td>+</td>
<td>thyroid OP, successful OP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>144</td>
<td>0</td>
<td>pHPT OP, no OP in follow-up</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. – 866</td>
<td>900</td>
<td>98</td>
<td>+</td>
<td>THPT OP, successful reoperation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. + 729</td>
<td>147</td>
<td>25</td>
<td>+</td>
<td>pHPT OP, successful reoperation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. + 362</td>
<td>169</td>
<td>26</td>
<td>+</td>
<td>thyroid OP, successful OP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. + 317</td>
<td>83</td>
<td>44</td>
<td>+</td>
<td>pHPT OP, successful reoperation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. – 982</td>
<td></td>
<td></td>
<td></td>
<td>multiple pHPT OP unsuccessful</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. + 563</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. + 1533</td>
<td>1000</td>
<td>26</td>
<td>+</td>
<td>THPT OP, successful reoperation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. + 282</td>
<td>157</td>
<td>32</td>
<td>+</td>
<td>pHPT OP, successful reoperation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. + 322</td>
<td></td>
<td>0</td>
<td>pHPT OP, no OP in follow-up</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. – 197</td>
<td>193</td>
<td>34</td>
<td>+</td>
<td>pHPT OP, successful reoperation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. + 601</td>
<td>140</td>
<td>24</td>
<td>+</td>
<td>pHPT OP, successful reoperation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. + 397</td>
<td>124</td>
<td>48</td>
<td>+</td>
<td>successful OP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. + 389</td>
<td>116</td>
<td>49</td>
<td>+</td>
<td>successful OP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21. + 797</td>
<td>89</td>
<td>17</td>
<td>+</td>
<td>successful OP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. + 255</td>
<td>93</td>
<td>18</td>
<td>+</td>
<td>pHPT OP, successful reoperation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. + 240</td>
<td>93</td>
<td>15</td>
<td>+</td>
<td>successful OP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Results of SVS, PTH values and surgical outcome of all patients. Two PTH peak values indicate double SVS.

Table 2 Fourfold table of all operated patients.

<table>
<thead>
<tr>
<th>All operated patients</th>
<th>OP +</th>
<th>OP –</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVS +</td>
<td>16 (84%)</td>
<td>2 (11%)</td>
</tr>
<tr>
<td>SVS –</td>
<td>1 (5%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 3 Fourfold table of patients with unsuccessful prior surgery.

<table>
<thead>
<tr>
<th>Reoperation</th>
<th>OP +</th>
<th>OP –</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVS +</td>
<td>8 (70%)</td>
<td>2 (10%)</td>
</tr>
<tr>
<td>SVS –</td>
<td>1 (20%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>2</td>
</tr>
</tbody>
</table>
related to Tc99m-Mibi SZ and US, can be explained by our highly-selective patient cohort, thus requiring the use of SVS, and should not be considered representative for the respective method. In 16 of 19 cases in our cohort, SVS concurred with intraoperative localization. True-positive results were found in 3 of 4 ectopic parathyroid glands. In the case of the fourth patient with a false-negative SVS, a mediastinal PTH peak was present, which subsequently concurred with intraoperative localization. However, the peak was not significant and was not considered true-positive for the study. In practice, however such results are also included in the decision regarding where to surgically explore. A PTH peak is never interpreted in isolation, but in the context of other PTH values on the anatomical drawing, the non-invasive diagnosis and the patient’s history and may provide a clue without particular significance in itself. The 3 cases with false-positive or false-negative results should be discussed, since a PTH peak does not rule out the presence of an adenoma in the face of absent intraoperative discoverability. On the other hand altered venous drainage resulting from prior surgery can negatively affect interpretation of the SVS. Thus, in a study by Reidel et al., 7 of 8 patients with incorrect SVS results had already had surgery on the thyroid. Other authors see no correlation between prior cervical surgery and non-concurrent SVS results [15–17]. In our cohort, 15 of the 19 patients undergoing surgery had already experienced surgery on the parathyroid gland (11) or the thyroid (4). In 12 of 15 cases with prior surgery, SVS concurred with intraoperative localization. Therefore we cannot likewise confirm a general trend. In individual cases a correlation between prior surgery and incorrect SVS cannot be ruled out with certainty. Thus one patient with a false-positive SVS had prior surgery on both the thyroid and parathyroid glands. After a negative non-invasive diagnosis and two SVS procedures, the adenoma was discovered on the opposite side of where the SVS indicated. This could be explained by altered venous drainage. Most published studies are devoted exclusively to preoperative diagnosis of persistent/recurrent HPT. Specifically, sensitivities of 91%, 78%, and 83% were achieved [15, 17, 18]. A study by Eloy et al. investigated the primary diagnostic benefit of SVS, reporting a sensitivity of 87% [19]. Compared to other publications, our results are at the same level, confirming the utility of SVS. SVS is certainly not the method for primary diagnosis of parathyroid gland adenomas. Initially, incremental diagnosis should use SZ and/or US, which in most instances is sufficient. If these methods produce contradictory or no results, further diagnosis should be pursued related to the initial situation and desired surgical method. Especially with respect to patients with persistent/recurrent HPT, accurate localization diagnostics are mandatory before reoperation, since due to anatomical changes and scarring of neck soft tissue, difficult operation conditions should be expected [20]. This applies analogously to other previous cervical surgeries. Thus the complication rate for recurrent laryngeal nerve paresis during reoperation is between 4 – 15%; for hypoparathyroidism with consecutive hypocalcemia the rate is 10 – 20%, whereas primary intervention shows a complication rate of only 1.45 – 3.40% [6]. The procedure used (CT, MRI or SVS) depends on availability and expertise of the relevant clinic, in addition to individual preferences, and must be selected on an individual basis. There is no uniform consensus in the literature, nor is there a guideline. Our experience shows that CT and MRI, as further diagnostic measures, currently offer a limited benefit. This is confirmed by other authors [13, 21]. Therefore in complicated cases, preference should be for SVS. This is an invasive examination method requiring expertise and which involves a risk of complication – however limited. However, SVS can provide the decisive indication for localization of the parathyroid gland in complex cases. A limitation of our study is certainly the low number of patients which reduced the statistical value of our results. However, it is comparable with the number of cases of other studies as well as the limitation to uncertain, non-invasive localization diagnostics and unsuccessful prior surgeries in the context of a seldom-indicated type of examination. In the Nuremberg Clinic, surgery is performed annually on approx. 50 parathyroid glands, but in the 11-year time frame under study, 26 SVS procedures were performed. This study confirms that SVS continues to be a useful diagnostic method for localizing parathyroid adenomas, and provides an opportunity for successful surgical therapy of HPT in selected cases.

Clinical Relevance of the Study

- The results of the study demonstrate the high sensitivity of selective venous blood sampling in the localization of a parathyroid hormone peak, and therefore the probable position of a parathyroid adenoma.
- The procedure is particularly appropriate if the non-invasive diagnosis is negative or ambiguous.
- Localization of a parathyroid hormone peak can support a second intervention when prior surgery has been unsuccessful, thereby reducing the surgical risk while increasing the chances of success.

Acknowledgements

We thank Günther Bollmann for helping us with the data acquisition, Fabian Klopfner for the illustrations and Dr. Manuel Schmidt for critical reading. This article was elaborated in fulfillment of the requirements of a medical doctoral thesis.

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