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GENERAL GYNECOLOGY

# Postoperative non-traumatic compartment syndrome (PNCS) in gynecologic surgery

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## Abstract

**Purpose** The postoperative non-traumatic compartment syndrome (PNCS) is a rare, but serious postoperative complication. Etiology, risk factors and clinical manifestation of PNCS are not well characterized since data in gynecologic and obstetric patients are limited.

**Methods** We performed a retrospective monocentric study of patients who underwent surgery for gynecologic or obstetrics conditions and identified five cases of PNCS, which were analyzed and compared to a control cohort in regard of incidence, clinical presentation, risk factors and clinical outcome.

**Results** Five cases of PNCS were identified among 19.432 patients treated between 2008 and 2019 with an incidence rate of 0.026%. The clinical examination was shown to be unreliable, lacking sensitivity in most clinical signs. Young age, obesity and long operation time were risk factors for the development of a PNCS. Fasciotomy for the treatment of a PNCS should not be delayed, since permanent function loss may occur early.

**Conclusion** A low threshold of clinical suspicion might be prudent to identify PNCS following gynecologic surgery. In the presence of the described risk factors, any suspicion of a PNCS should be evaluated further and if necessary treated with fasciotomy urgently.

**Keywords** Postoperative complication · Gynecologic surgery · Non-traumatic · Compartment syndrome · Risk factors

## Introduction

The postoperative non-traumatic compartment syndrome (PNCS) is an uncommon, yet potentially life-threatening postoperative complication which represents, due to its rarity, a diagnostic challenge for the surgeon. The etiology and predisposing factors are not well understood, since only 124 cases of PNCS have been described in the literature between 1970 and 2013 [1].

Several variables are thought to contribute to the risk of developing the PNCS after gynecological or obstetrical operations. So far a body mass index higher than 25 kg/m$^2$ [2], an operating time longer than 300 min [1, 3], lithotomy position (Lloyd-Davies-position) [2, 4, 5], a high blood loss and intraoperative hypotension [6, 7] have been identified as risk factors by different authors.

When caused by a trauma, compartment syndrome develops due to an impaired local blood flow. This causes ischemia and tissue edema and thus creates a vicious circle of rising intra-compartmental pressure by further decreasing blood flow inside the compartment [8]. Similarly, in PNCS it is hypothesized that a reduced arteriovenous gradient in the affected lower extremity triggered by an arterial hypoperfusion (e.g. lower extremities being positioned above the level of the heart) or by a venous obstruction (kinking of the veins or external pressure) causes an impaired blood flow with a consecutive rise in intra-compartmental pressure [4, 8, 9].

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Traditionally, the clinical examination has been regarded as the first approach in the diagnosis of a compartment syndrome [10, 11], and the "6-Ps"-complex comprising pain, paresthesia, paralysis, pallor, poikilothermia and pulselessness has been used to describe its clinical picture [12–14]. Of note, this clinical symptom complex has been described in the context of traumatic compartment syndromes and thus its validation and clinical use in the diagnosis for a PNKS has not been evaluated so far.

As a further diagnostic approach, direct measure of intra-compartmental pressure has been described for the diagnosis of a compartment syndrome. Historically, a pressure higher than 30 mmHg inside the compartment was regarded as the threshold for establishing the diagnosis. Lately, however, it has been recommended to compare the intra-compartmental pressure with the diastolic blood pressure due to a higher correlation with intra-compartmental tissue perfusion. According to some authors, compartment syndrome must be assumed if the difference between the patient´s diastolic blood pressure and the intra-compartmental pressure is less than 30 mmHg [15], while others point out that this threshold could result in unnecessary fasciotomies as it showed a low specificity [16].

Since the rise of intra-compartmental pressure is the most important factor in the establishment of the compartment syndrome, fasciotomy for decompression of the compartment represents the gold standard treatment [11, 17–20].

The procedure is carried out as an urgent intervention, since any delay of proper treatment raises the risk of permanent damage with persisting residual sensomotoric deficits of the affected limb [14]. A delayed diagnosis and treatment of a compartment syndrome may necessitate an amputation of the affected limb as ultima ratio. The amputation rate has been estimated to be as high as 13% in traumatic compartment syndrome [21], while in PNCS it amounts to less than one percent of published cases [1].

The aim of our study was to further characterize the PNCS after gynecologic and obstetrical operations with particular focus on its clinical presentation, risk factors and potential residual symptoms.

## Methods

In April 2019, we conducted a search in the hospital database of our institution (Department of Gynecology, Diakonie Kliniken Kassel, Kassel, Germany; hospital information system: Orbis, Agfa, Morstel, Belgium) for patients who underwent surgery due to gynecological and obstetric conditions between January 2008 and March 2019. If a patient was operated several times during the study period, each surgical intervention was counted separately.

All cases were reviewed and both mean value and confidence intervals were determined for (I) age at the time of the operation, (II) body mass index and (III) duration of the procedures. Further we reviewed if the underlying disease was (IV) obstetrical or gynecological, wether it was (V) benign or malignant and if (VI) lithotomy or (VII) Trendelenburg-position was used during the procedure.

In addition the study cohort was reviewed for cases of postoperative non-traumatic compartment syndrome of the lower extremities and the medical records of these patients were independently analyzed by two reviewers (SY and MPR). Parameters of interest in patients with PNCS were: prevalence of the symptoms previously described in literature (pain, paresthesia, paralysis, pulselessness, pallor), time from the end of the procedure to the onset of symptoms and from the onset of symptoms to surgical therapy, side of the PNCS, type of surgical therapy and type of functional impairment still present at the time of discharge from the hospital. The group of patients with PNCS was compared to the group of patients without this complication in regard to the parameters (I)–(VII). Parameters (I)–(III) were compared using an unpaired *t*-test and parameters (IV)–(VII) were compared with a $\chi^2$ test with Yates correction. Due to a limited sample size of the group of patients with PNCS, no multivariate analysis was included in the statistical evaluation of our data. A *p*-value of 0.05 or lower was considered to be statistically significant.

Traditionally, compartment syndrome is associated with the symptoms of the "6-Ps-complex" (pain, paresthesia, paralysis, pallor, pulselessness and poikilothermia) [12–14]. Patients with PCNS in our study cohort were reviewed for the presence of these P-symptoms. Furthermore, we reviewed if previously described risk factors for a PCNS were present in these patients: BMI higher 25 kg/m$^2$, intraoperative hypotension, lithotomy position, Trendelenburg position, operation time longer than 300 min [1–3, 6, 7] (Tables 2, 3).

Lollo et al. described that a delay of PNCS treatment by fasciotomy of more than 5 h following the onset of first clinical symptoms significantly increases the risk of developing sensomotoric deficits. Accordingly, we compared the incidence rate of persistent functional impairment at discharge for patients in which the surgical treatment was initiated 5 or more hours following first clinical symptoms as recorded in the patient chart to PNCS patients in which a fasciotomy was carried out within the first 5 h of PNCS manifestation.

Data were analyzed after anonymization with statistical analysis software (SPSS, IBM, Amonk, NY, United States).

## Results

Between January 2008 and March 2019, 19.432 surgical procedures were performed for gynecological or obstetrical reasons at our institution. In this cohort five cases of

PNCS were identified, corresponding to an incidence rate of 0.026%. PNCS occurred in two patients with endometrial cancer (abdominal radical hysterectomy with lymph node dissection), one patient with cervical cancer (laparoscopic radical hysterectomy with lymph node dissection), one patient with deep infiltrating endometriosis (laparoscopic resection of endometriosis) and one patient with prolonged labor (cesarean section with intraoperative hemorrhage due to atonia). Mean time from end of initial surgery to the onset of clinical symptoms was 9.6 h. Fasciotomy was performed on all five patients. The mean time between the beginning of symptoms and decompressing fasciotomy was 3.6 h. Out of three patients who underwent fasciotomy within 5 h after the onset of PCNS symptoms, one patient showed residual symptoms at the time of discharge while both patients with fasciotomy after 5 h of PCNS symptoms had residual symptoms at time of discharge (Table 1).

When compared with our study cohort, patients with PNCS were significantly younger (age in years: 32.6 vs. 57.2; $p < 0.01$), underwent more extended surgery (operation time in minutes: 252 vs. 102; $p < 0.01$) and had a higher body mass index (34 vs. 27.3 kg/m$^2$; $p = 0.01$). Of note, all patients with PNCS had a body mass index of more than 25 kg/m$^2$. Additionally, patients in our cohort operated for malignant diseases had a significantly higher risk of developing a PNCS than those with benign diseases (OR 10.08; $p = 0.034$). There was no significant difference in the risk of developing a PNCS when patients were positioned in Trendelenburg position opposed to a non-Trendelenburg position ($p = 0.38$). We also did not find a significant difference in the risk of developing a PNCS when patients were positioned in lithotomy position compared to patients positioned in a non-lithotomy position ($p = 0.3$) (Table 2).

Regarding clinical symptoms previously associated with a compartment syndrome we found a heterogenous picture in our cohort. Pain was the only symptom present in all patients. Three patients had paraesthesia but clinical symptoms previously described (paralysis, pulselessness and pallor) [12–14] were not observed in our patient cohort (Table 3). All cases of PNCS in our study were unilateral. Four were localized on the right lower extremity and one affected the left lower extremity.

## Discussion

The frequency of PNCS has been reported to vary between 0.02 and 0.2%. These estimates are based on heterogenous cohorts with a high proportion of male patients [3, 5].

Less is known about the frequency of the PNCS in female patients after gynecologic surgery. Bauer et al. estimated the incidence rate between 0.067 and 0.28% based on questionnairs answered by 59 gynecological departments in Germany. However, the authors pointed out, that their survey had a response rate of 35% and that the estimated incidence could be biased due to selective response [22]. Tomassetti

**Table 1** Patients with PNCS

| | | | | | |
|---|---|---|---|---|---|
| Age (years) | 31 | 39 | 25 | 26 | 42 |
| BMI (kg/m$^2$) | 39 | 28 | 35 | 35 | 33 |
| Inital diagnosis | Early-stage cervical cancer | Endometriosis of the ureter | Early-stage endometrial cancer | Failure to progess in labour | Early-stage endometrial cancer |
| Inital surgical therapy | Endosopic radical hysterectomy | Endoscopic endometrioma resection | Abdominal hysterectomy; retroperitoneal lymphadecectomy | Cesarian section | Abdominal hysterectomy; retroperitoneal lymphadenectomy |
| Inital operation time (mins) | 270 | 303 | 332 | 45 | 312 |
| Position during inital surgery | Lithiotomy | Lithiotomy | Lithiotomy | Lithiotomy | Lithiotomy |
| Time to onset of signs/symptoms (h) | 12 | 5 | 25 | 1 | 5 |
| Time between first signs/symptoms and treatment (h) | 1 | 1 | 6 | 3 | 7 |
| Location of compartment syndrom | Unilateral right | Unilateral right | Unilateral right | Unilateral right | Unilateral left |
| Type of treamtent | Fasciotomy, two-stage secondary suture | Fasciotomy, two-stage secondary suture | Fasciotomy, two-stage secondary suture | Fasciotomy, primary closure | Fasciotomy, two-stage closure with prosthetic mesh |
| Functional outcome upon discharge | Prolonged pain; no motorsensoric deficit | None | Superficial nervus perineus lesion | None | Deep nervus perineus lesion |

**Table 2** Risk factors for PNCS

| | Operations without PNCS | | Operations with PNCS | | |
|---|---|---|---|---|---|
| *N* | 19.427 | | 5 | | |
| | Mean | Confidence interval (95%) | Mean | Confidence interval (95%) | *p*-value |
| Age | 57.22 | 56.99–57.31 | 32.6 | 23.14–42.06 | < 0.01 |
| BMI (kg/m$^2$) | 27.31 | 27.23–27.39 | 34 | 29.04–38.96 | 0.01 |
| Duration of surgery (min) | 101.5 | 101.07–101.93 | 252.4 | 106.12–398.68 | < 0.01 |
| | | *N* | *N* | | *p*-value |
| Trendelenburg-positioning | | 9001 | 1 | | 0.46 |
| Non Trendelenburg-positioning | | 10.426 | 4 | | |
| Lithiotomy positioning | | 13.205 | 5 | | 0.29 |
| Non lithiotomy positioning | | 6222 | 0 | | |
| Obstetrics diagnosis | | 6121 | 1 | | 0.94 |
| Gynceologic diagnosis | | 13.306 | 4 | | |
| Beningn diagnosis | | 18.224 | 3 | | 0.028 |
| Malignant diagnosis | | 1203 | 2 | | |

**Table 3** Signs and symptoms assosciated with PNCS [6, 7]

| | Patiens with sign/symptom (*n*) | Patients without sign/symptom (*n*) |
|---|---|---|
| Paraesthesia | 5 | 0 |
| Paraesthesia | 3 | 2 |
| Pallor | 0 | 5 |
| Paralysis | 0 | 5 |
| Poikliothermia | 0 | 5 |
| Puleslessness | 0 | 5 |

et al. found an incidence rate of 0.8% in a retrospective analysis of patients operated for deep infiltrating endometriosis [23].

In our study we evaluated the incidence of PCNS in a homogenous (all gynecologic or obstetrics patients) and representative patient cohort. We found an incidence rate of 0.026% which was lower than the frequency published by Bauer et al. thus supporting the possibility of a bias in their estimate.

Obesity has been previously described to be associated with an increased risk of developing a PNCS. Peters and colleagues examined the effect of the lithotomy position on the blood pressure of the lower extremities in healthy volunteers. They observed that reduction in ankle pressure in the lithotomy position was significantly greater in subjects with a BMI of 25 kg/m$^2$ or more (Peters 1994). Contrary, Christoffersen et al. concluded in their study that the BMI was not associated with a PNCS. However, the latter analysis was carried out on all PNCS-cases in Denmark thus representing a very heterogeneous group with only 32.5% of patients being female and merely 12.5% of cases after gynecologic surgery. Furthermore, there was no information on the BMI in these specific subgroups.

In our study, we found that the patients with PNCS had a significantly higher BMI than patients without this complication and that no patient with a BMI lower than 25 kg/m$^2$ developed a PNCS. As only one third of all PNCS-cases published between 1970 and 2013 occurred in female patients, it could be possible that female patients have a lower baseline risk of developing a PCNS [1, 2].

Young age has been previously identified as a potential risk factor for the development of a compartment syndrome. This can be observed in patients with traumatic compartment syndrome which are mostly younger than 35 years [24]. It also seems to be the case in non-traumatic compartment syndrome. Bauer et al. collected all published cases of PNCS after gynecologic surgery and found these patients to have a median age of 33 years [25]. Based on their retrospective studies both MacIntosh et al. and McQueen et al. hypothesize that high muscle volume in an inelastic osseofascial compartment contributes to the development of a compartment syndrome [8, 24, 26].

Our observations showed patients with PNCS to be significantly younger (mean age of 32.6, 95% CI 23.1–42.1) than patients without, thus supporting previous observations.

It has been hypothesized that the elevation of legs during a lithotomy-position (Lloyd-Davies-position) reduces local blood flow in the lower extremities due to a reduced arteriovenous gradient. Consequently oxygenation of the compartment tissue may become insufficient eventually leading to the development of the PNCS [2, 4, 5]. Halliwill

et al. and Peters et al. studied lower limb blood pressure in eighteen healthy volunteers in lithotomy position and observed a mean arterial pressure decrease of approximately 0.75 mmHg for each centimeter the lower extremity was elevated [2, 5]. The local blood pressure of the lower limb dropped further with the bed tilted 15° head-down due to the increased arm-to-ankle vertical distance [5]. Bauer et al. noticed that all of their analyzed PNCS-cases occurred after procedures in lithotomy-position, thus emphasizing the importance of leg elevation in the development of this complication [22]. Similarly, we observed that all patients with PNCS in our case series were operated in lithotomy position compared to 68% of patients without this complication. We did not find a statistical significant relationship between lithotomy or Trendelenburg position and the development of the PNCS, but we believe this could be related to the small case number of the PNCS cases with a possible type-II error.

Total surgical duration appears to be a pivotal factor in the development of PNCS. Sheridan et al. studied the effects of pressure inside the anterior tibial compartment in *oryctolagus cuniculus* and found first neuromuscular deficits after exerting an intra-compartmental pressure of 40 mmHg for 6 h. The functional losses were more pronounced with increasing pressure and duration of pressure application [9].

These observations are consistent with those made in an analysis of 40 PNCS-cases identified by a nationwide database search in Denmark. The operation preceding these PNCS-cases had a median duration of 6 h and no case of PNCS was observed after a procedure lasting shorter than 3.5 h [1]. Similar results were obtained in a retrospective analysis of 65 PNCS-cases after urologic procedures in lithotomy position. In only two of these cases operation time was found to be shorter than 4 h [3]. Hefler-Frischmuth and colleagues collected all published cases of PNCS after gynecologic procedures and found a median operation time of 5.4 h [27].

In line with these findings, in our study, mean operation time in patients with PNCS was also significantly longer (mean operation time 4.2 h or 252.4 min, 95% CI 106.1–398.7) compared to the total study cohort.

Historically, a symptom complex known as the "6-Ps" (pain, paresthesia, paralysis, pallor, poikilothermia and pulselessness) has been used to describe the clinical picture of the traumatic compartment syndrome. Some authors stated that the clinical examination based on this symptoms and signs is reliable to confirm or exclude compartment syndrome [10, 11]. Contrary, the American Academy of Orthopaedic Surgeons outlined, that reliance on clinical examination may lead to both missed compartment syndrome and unnecessary fasciotomies [17]. Janzing et al. performed a prospective study in order to compare the different diagnostic approaches of this condition. They showed that the clinical examination (pain with stretch, sensibility, swelling ect.) had a sensitivity of 67% and a specificity of 89% [16]. Mithöfer et al. showed in a retrospective analysis that pain was the only symptom always present in patients with compartment syndrome, thus showing the highest sensitivity. Paresthesia was the second most common symptom in these studies (63% of cases) while motoric symptoms and pulselessness were present in 42% and 21% of cases respectively [14]. It should be emphasized that these studies were performed on patients with traumatic compartment syndrome and that data regarding the PNCS are scarce and solely relying on case reports. Our observations showed that pain was the only symptom always present in patients with PNCS, followed by local paresthesia in 3 of 5 cases (Table 3). Other symptoms like motoric deficits or pulselessness were not observed. In traumatic compartment syndrome pain can be rather unspecific, since it could reflect the tissue damage caused by the trauma itself. On the other hand, pain in the lower limb after an operation and without preceding trauma should raise the suspicion of PNCS.

Of various blood tests examined for the diagnosis of compartment syndrome, creatine kinase and myoglobin were proposed as diagnostic markers. Hefler-Frischmuth et al. showed by reviewing the published cases of PNCS after gynecologic surgery that the mean value of postoperative creatin kinase and myoglobin was 19.223 U/L and 1248 µg/L respectively. In addition, they collected a control group of 300 patients and measured the postoperative creatin kinase and myoglobin to establish reference values. They found that 299 patients out of this control group had values under 1000 U/L and 1000 µg/L respectively [27].

Magnetic resonance imaging (MRI) represents an additional help in diagnosing an established compartment syndrome. It is able to detect muscle edema and enhanced compartments after gadolinium-based contrast agent, which reflects disturbances in cell membrane permeability. However, the MRI seems to have low sensitivity in recognizing imminent compartment syndrome [28]. In any case, an MRI should not delay surgical therapy and only should be performed in clinically ambiguous cases.

Different techniques have been examined and tested for the measurements of intracompartmental pressure and diagnosis of compartment syndrome [15, 29]. It should be pointed out that the benefit of pressure measurement and the thresholds, which establish the diagnosis of a compartment syndrome, are still debated [30, 31]. A retrospective study of traumatic compartment syndromes by Lollo et al. showed that intracompartmental pressures ranged from 30 to 140 mmHg [21]. Mubarak et al. recommended fasciotomy as soon as compartment pressure exceeds 30 mmHg [32]. Whitesides et al. on the other hand favour the operation if intracompartmental pressure rises to within 30 mmHg of the diastolic blood pressure [15]. White et al. support the latter threshold, since they

observed in patients with tibial fracture that intracompartmental pressures above 30 mmHg do not cause compartment syndrome as long as diastolic blood pressure exceeds it by more than 30 mmHg [33]. Yet a prospective study by Prayson et al. showed that 84% of patients with tibial fracture and compartment pressure within 30 mmHg of the diastolic pressure did not develop compartment syndrome [34]. This supports the results of Janzing et al. who found that a difference between diastolic blood pressure and intracompartimental pressure lower than 30 mmHg had a low specificity of 65% [16], making this threshold debatable and increasing the need for further research.

In summary it appears reasonable to have a low grade of suspicion for the PNCS in clinical practice, since the early diagnosis and operation is paramount for the patient. Matsen et al. reviewed 14 cases of patients with compartment syndrome of which two were initially treated without fasciotomy (analgesia, steroids, plasma expanders). Eventually fasciotomy became mandatory in both patients, but due to the delayed operation one patient suffered permanent loss of muscle function and the other sustained amputation due to infection of the limb [13]. The authors concluded that conservative therapy is rather harmful due to its delay of the operation. They noted that no permanent functional impairment was observed in their case series if fasciotomy was performed within 12 h. In contrast, Lollo et al. observed in their case series that permanent sequelae occurred if operative therapy was performed after a mean time of 5.3–7.7 h [21]. In our cases we observed that if fasciotomy was performed within 5 h permanent symptoms were observed more rarely (one out of three) but still could occur. We think that the conclusion of Matsen et al. which states that permanent symptoms only develop if compartment decompression is delayed for more than 12 h, is inaccurate. It should be noted that out of the five cases in their study which didn't sustain any permanent damage, four were operated within 3 h and only one was operated 10 h after the beginning of symptoms [13]. Consequentially, we think that there is not much scientific support for establishing a safe time interval for which a compartment syndrome can be allowed to persist and that fasciotomy should always be performed as soon as possible. It should be emphasized that, based on the published cases in literature, 75% of patients with PNCS suffered from permanent deficits [1].

This is also important from a medicolegal point of view. Both Bauer et al. and Shadgan et al. reported that of the legally completed cases, 55% were considered malpractice and had an unfavourable outcome for the medical staff involved [22, 26].

In our patients with PNCS fasciotomy was the treatment of choice as this is widely accepted as the gold standard therapy [11, 18–20].

There are only limited data concerning preventive measures against the PNCS. MacIntosh et al. and Turnbull et al. deduced from the pathophysiology of this complication, that time in lithotomy position and pressure on the lower limbs should be minimized [4, 8, 23].

## Conclusion

PNCS represents a rare complication after gynecologic and obstetrical operations, which necessitates immediate surgical therapy. To the best of our knowledge, this is the first study which demonstrates that factors like high BMI, operation length and young age risk factors for PNCS in gynecological patients. Our data indicate that the risk for permanent sequelae rises as surgical therapy is delayed in PCNS. Based on our results, it is not possible to determine a "safe time interval" in which a compartment syndrome doesn´t leave permanent damage.

**Author contributions** ML, SY and MPR were responsible for the conception and design of the study, interpretation of data and drafting the manuscript. SY contributed substantially to the acquisition of the data. ML, SY and MPR performed statistical analysis of the data and revised the manuscript critically for intellectual content. AM and JCR contributed substantially to the analysis of the data. AF and TB were involved in designing the study with regards to anesthesiological and vascular surgical aspects and made substantial contributions in interpretation of data and editing of the manuscript. BA was involved in the critical revision of the manuscript. All authors reviewed the manuscript and contributed to the final submission.

### Compliance with ethical standards

**Conflict of interest** We declare that we have no conflict of interest.

**Ethical approval** The study was conducted in concordance with the ethical standards of the institution.

**Informed consent** Only retrospective data from patient records have been analyzed. No intervention was performed and all patients were treated according to the existing clinical guidelines. All patients gave their agreement to analyze and publish data anonymously before treatment.

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