Relationship between intraperitoneal pressure and the development of hernias in peritoneal dialysis: confirmation for the first time of a widely accepted concept

"This is an accepted version of the article published in International Urology and Nephrology. The final authenticated version is available online at: 10.1007/s11255-023-03663-5

Abstract

Background: Intraperitoneal pressure (IPP) in peritoneal dialysis (PD) is an individual characteristic that can be modified by posture and intraperitoneal volume (IPV). It is considered one of the predisposing factors for complications in the abdominal wall, such as the appearance of hernias. No studies to date have confirmed this. The main aim of this study was to assess the relationship between the development of hernia in incident PD patients and IPP measured at PD onset.

METHODS: A prospective observational study of incident patients in a PD programme between 2010 and 2020. IPP was measured using the Durand's method.

RESULTS: One hundred and twenty-four incident patients on PD, 68% male, mean age 62.1 ± 15.23 years, body mass index (BMI) 27.7 ± 4.82 kg/m^2, 44% were diabetic. IPP in supine was 16.6 ± 4.60 cm H_2O for a mean IPV of 2047.1 ± 359.19 mL. Hernias were reported in 18.5% of patients during PD follow-up: 57% were inguinal hernias, 33% umbilical and a further 10% presented in a combined form. PD hernias correlated positively with IPP in supine position (p=0.037), patient age (P=0.008), BMI (p=0.043), a history of prior hernia (0.016), laparoscopic catheter placement (p=0.026) and technique failure

(p=0.012). In the multivariate analysis, a higher IPP was independently related to the development of hernias (p=0.028).

CONCLUSIONS: The development of hernias in PD was related to a higher IPP at PD onset, older age, higher BMI, history of prior hernia, catheter placement by laparoscopy and technique failure.

Key Words: Abdominal wall, hernias, intraperitoneal pressure, leaks, peritoneal dialysis.

Introduction

One of the complications of peritoneal dialysis (PD) is the increase of intra-abdominal pressure (IAP). A study conducted among PD patients showed that IAP measured through a urinary catheter is equivalent to the intraperitoneal pressure (IPP) that is measured through the PD catheter with the patient in supine position (1). The most widely used method for measuring IPP in PD units is that described by Durand, connecting a twin-bag to the PD catheter with the patient in supine position (2). This method was recently validated by a Spanish study group who connected a central venous pressure system open to atmospheric pressure to a three-way connector located between the peritoneal catheter and the PD bag (3).

IPP is an individual variable in patients on PD. The IPP is influenced by several factors: it increases with the Body Mass Index (BMI), (4–10), comorbidities (6,9), and the prescribed intraperitoneal volume (IPV). An increase of 1 cm H_2O for every 500 mL of IPV can be observed on the basal value of IPP (4). Similarly, upright position, physical activity, Valsalva manoeuvres and jumping also produce an increase in IPP (11).

IPP is valued systematically in paediatric PD units to prevent abdominal wall complications (12), adjust dialysis infusion and optimise ultrafiltration (13). In adult PD units, IPP is not routinely measured, although recent guidelines for assessing dysfunction of the peritoneal membrane in adults recommend measuring IPP as an additional test in research studies (14).

In adults, IPP is considered pathological if it is higher than 18-20 cm of H_2O and associated with a reduction in vital lung capacity (15). Possible consequences of a high IPP in patients on PD include: harmful haemodynamic effects, decrease in vital lung capacity (16,17), lower ultrafiltration rate (13,18,19) and abdominal wall complications (4,12,16,17).

Abdominal wall complications are more frequent in PD than in haemodialysis (HD), and are consequently attributed to the prescribed IPV that increases IPP. Abdominal wall complications in PD are related to technique failure, especially in the first few months (20). Anatomical and hydrostatic factors intervene in the aetiology of hernia in the PD population (21). Other factors include: older age, polycystic kidney disease (PKD), BMI, multiparity and a history of prior hernia (22–24). IPP has always been considered a predisposing factor for abdominal wall complications but no studies in adults have confirmed this hypothesis.

A high IPP has been related to the appearance of hernias and leakages in the paediatric PD population (12).

The main aim of our study was to assess the relationship between the IPP measured at the start of the technique and the appearance of hernias in incident patients on PD. The secondary aim was to study the factors related to IPP in our PD population.

Materials and Methods

This was a prospective, observational study of our stable PD incident patients during the years 2010-2020. IPP was measured at 2-3 months after starting PD, coinciding with the first peritoneal equilibration test (PET). This study was approved by the Institutional Ethics and Research Committee (CEIm) of the Parc Taulí University Hospital in Sabadell (Barcelona), reference number: 2020/700. Written informed consent was obtained from all patients.

Two puncture techniques were used for catheter placement: Y-TEC trocar and Seldinger technique. The peritoneal dialysis catheter was inserted into the peritoneal cavity through a paramedian incision, the catheter passed through the body of the rectus muscle. The deep catheter cuff was placed in the thickness of the rectus muscle. The external cuff was placed in the subcutaneous tunnel and the exit site was oriented so that the catheter is directed either inferiorly.

Laparoscopic procedures were performed under general anesthesia in operating room environment. A trocar with umbilical location was used for the camera with a diameter of 10 mm. The laparoscope was used to simply monitor the positioning of the catheter tip within the peritoneal.

IPP was measured using the technique described by Durand et al. in 1992 (2). Two measurements are made while the patient remains in supine position and horizontal plane. The IPV being the volume drained prior to PET. A twin-bag is connected to the catheter and an empty drainage bag is hung on a stand with a scale graduated in centimetres and a perpendicular stick. Zero level is set at the medial axillary line. The connection catheter is then opened and the drainage line is filled with dialysis fluid. After stabilisation of the column level, IPP values

are recorded the first after deep inspiration and the second after deep expiration and the mean is calculated. Once measured, the patient's abdominal fluid is emptied and the drain volume recorded. Results are expressed in cm of H_2O. The procedure is repeated in a sitting position, considering the anterior superior iliac spine as level 0. The measurement is taken by trained nurses in the PD unit, following a long dwell of 2L of PD solution (Physioneal 2.27%; Baxter Healthcare Corporation, Deerfield, IL, USA).

The following data were recorded: demographic (age, gender), anthropometric (weight, size, BMI), history of arterial hypertension, diabetes mellitus (DM), aetiology of chronic kidney disease (CKD), Charlson Comorbidity Index (CCI) (excluding age), history of PKD, number of pregnancies, prior abdominal surgery, prior abdominal hernia and catheter placement technique. At the end of the monitoring, the following information was recorded: prescribed PD technique, peritoneal function, number of peritonitis episodes, appearance of hernias and leakages. End of treatment was recorded and technique failure was defined as death or transfer to HD.

Statistical Analysis: Quantitative variables were described as mean +/- standard deviation (SD) and qualitative variables as frequencies and percentages. Univariate association between the appearance of hernias and qualitative variables was evaluated with the chi-squared test and for quantitative variables by means t-student test. Significant variables at P-value of <0.2 were introduced in a multivariate logistic model and only those with significant level P-value <0.05 were retained in the final model.

Results

A total of 124 incident patients on PD were studied, 68% were male with a mean age of 62.1 ± 15.23 years, BMI of 27.7 ± 4.82 kg/m^2; 44% were diabetic and 4% had a history of PKD. With reference to comorbidity, they presented a mean CCI of 4.8 ± 1.92. A history of previous surgery was found in 13% and 8.9% had a history of treated abdominal hernias. PD catheter was placed in 71% of cases by a trained nephrologist by percutaneous technique and in 29% by laparoscopy. The mean follow-up time was 21.36 months (range: 9.56 – 40.7). In 38.3% of patients, automated peritoneal dialysis was initially performed, 76% began on a wet day with mean daily volume of 1527.8 ± 798.06 mL. Mean residual diuresis was 1367.8 ± 781.01 mL (Table 1).

IPP in supine position presented a mean of 16.6 ± 4.60 cm H_2O (range: 6.5-28.5) per mean IPV of 2047.1 ± 359.19 mL, 25.8% had an IPP ≥ 20 cm H_2O. Mean IPP in a seated position was 27.8 ± 5.22 cm H_2O (range: 15.5-41.0) with an excellent correlation between both ($r=0.644$, $P<0.001$). In seated position IPP increase was 75 ± 40% compared to supine.

Hernias developed in 18.5% of the patients during PD follow-up: 57% inguinal, 33% umbilical and 10% presented a combination of both. A mean time of 7.9 months (range: 3.1-17.4) was calculated from PD catheter placement to the appearance of the hernia and 48% of the recorded hernias presented in the first six months following PD onset. The coincidence of hernias and leaks almost reached significant levels ($p=0.053$) in 32% of patients. Leaks appeared in the first 30 days of catheter placement in 36% of cases.

In relation to gender, 21% of males developed hernias vs. 12.8 % of females, without statistical significance ($p=0.22$). No woman without previous pregnancy

developed hernias during PD follow-up. History of hernia prior to PD correlated positively with the development of hernias in PD (p=0.016). Regarding catheter placement technique, 30.6% of patients whose catheter was placed using laparoscopy developed hernias, versus 20% (p=0.026) when placement was done by percutaneous technique. The peritoneal dialysis catheter was placed by laparoscopy in 37 patients, 11 of them developed hernias. Five patients (13,5%) presented umbilical hernias and two of them combined umbilical and inguinal hernias. The peritoneal dialysis catheter was placed by puncture techniques in 87 patients, only 4 (4.5%) umbilical hernias were recorded. No incisional hernia was developed in the entry-site of the peritoneal catheter.

The appearance of hernias in PD correlated positively with IPP in supine position (p=0.037), patient age (p=0.008) and BMI (p=0.043). There was no relationship with CKD aetiology, DM, CCI, history of PKD, or prior abdominal surgery (Table 2). In the multivariate analysis, the presence of hernia in PD was considered the dependent variable, a lower D/P creatinine (p=0.042) and higher IPP (p=0.028) were significant (Table 3) (Figure 1). We studied the variables related to the D/P creatinine and found that the D/P creatinine inferior to 0,70 was associated with female gender (p=0.024) and a history of PQR (p=0.023). Patients with hernias in PD presented more technique failure (death or transfer to HD) compared to patients without hernias, 65% vs. 36.6 % (p=0.012).

IPP was positively related to age (r=0.290, p=0.001), BMI (r=0.569, p<0.001), CCI (r=0.344, p<0.001), a history of DM (p=0.001), pregnancies (P=0.034), females with 3 or more pregnancies (p=0.001). It is interesting to highlight a

negative correlation between IPP and serum creatinine (r=0.210 and p=0.019). There was no relationship of IPP to gender, history of PKD, causes of CKD, history of prior hernia, prior abdominal surgery, or type of PD (Table 4) (Fig 2).

Discussion

The appearance of hernias in patients on PD has been related to older age, higher BMI, and a history of prior abdominal hernia. According to available published studies, a relationship between high IPP and the development of hernias has been shown in PD for the first time in adults. High IPP is related to higher BMI, older age, greater comorbidity, history of DM and multiparity.

Hernias are a frequent complication in the adult PD population; several series document an incidence of between 11% and 25%, with a predominance of inguinal and umbilical hernias (21,22,25,26). A similar incidence (18.5%) was found in our population, with a predominance of inguinal (*57%*) and umbilical (33%) hernias. The mean time from catheter placement to the appearance of hernia was 7.9 months, while in the literature there is a great variability of time, which fluctuates between 5 and 16 months (22–24). Hernias were more frequently found in males, 21.2% vs. 12.8% in females, without reaching statistical significance, in concordance with most authors (23,27,28). In our study, females without previous pregnancies did not develop hernias in PD. An increase in hernias in women with more than 3 pregnancies was observed (22,25). Pregnancy produces a physiological increase in IAP and may be a predisposing factor for future abdominal wall problems.

Patients with a history of abdominal hernias are considered at risk of developing hernias in PD. This finding is in agreement with previous studies (22,24).

In relation to catheter placement, 30% of patients with catheters placed by laparoscopy developed hernias in comparison to 20% where a percutaneous technique was used, with a statistically significant relationship. The laparoscopic technique increases the appearance of umbilical hernias in comparison of puncture technique (14.5 % vs 4.5 %), although some patients had a combined hernia (umbilical and inguinal). It is not recommended to use insert the laparoscopic trocar with umbilical location to avoid the future incisional hernias(29).This is a possible explanation for this results in addition to patients' comorbidity, and it advise us to review our technical procedures.

No relationship was established with CKD aetiology, history of DM or of PKD: of the five patients with PKD in our series, two presented hernias. It is well known that 10% of PKD patients may present abdominal hernias among possible extra-renal manifestations (40). Several studies report that a history of PKD predisposes the development of hernias in PD (23,30–32). The small number of patients with PKD in our series and the short follow-up may determine the absence of statistical significance in our results.

A relationship with older age, higher BMI and higher IPP was found in the appearance of hernias. With regard to age, one study found that patients over 40 have a higher risk of presenting hernias (22); the remaining series do not consider it a predisposing factor (23–25,28,33,34). These results may be related to our mean age of 62 years, higher than other series. BMI in the general population is associated with greater risk of hernia, especially umbilical (23), and is consistent with our results. In 2003, del Peso et al. found BMI to be a factor of risk for presenting complications in the abdominal wall, but was more

closely associated to leakages (33). However, in some PD patients, low weight has been reported to be a risk factor for presenting hernias, possibly associated with muscular wall weakness and malnutrition (33). In 2011, Gracia et al. failed to find any relationship between hernias and BMI (24).

We must note that high IPP has a statistically independent relationship to hernias in PD. Hernias are included systematically in all reviews on complications related to the IPP increase in PD (35). This relationship has been studied and shown in the paediatric population (12) but has not been confirmed in the adult PD population, although several authors have recorded a trend towards statistical significance (5,6). Multivariate analysis found that a lower D/P creatinine in the first PET is associated with hernias in PD. To our knowledge, no similar results have been reported in other studies.

The development of hernias in PD was related to technique failure defined as death or transfer to HD. Approximately 9% of the causes of early failure were related to abdominal wall complications such as hernias (29,30). In our PD patients, hernias were related to older age and higher BMI, factors of mortality risk in the general population which also account for these results.

Patient with hernias in PD also presented leaks in 32%, often simultaneously. This may be related to abdominal wall defect (36,37). Late leakages are considered unpredictable, and are related to female gender in some reviews (38,39). In our series, 36% of the recorded leakages appeared in the first 30 days following catheter placement. Some studies have reported that older age and high BMI are predisposing factors to leakages (23), but there are no published studies that relate them to IPP. We also failed to establish this relationship.

With reference to IPP, the mean was 16.6 ± 4.6 cm H_2O, which is higher compared to other published series (2,4,7–9,19). The relationship between IPP and BMI is frequently described (4–10), in accordance with our data. Older patients in our sample had higher IPP, unlike other published studies (4,5,8,9), possibly because they include younger patients. IPP correlates to CCI and a recent multi-centre study presented similar results (9). There are no records relating IPP with a history of DM (4,5,8), but in our patients, DM was related to greater IPP. We failed to find a relationship between PKD and high IPP. A recent study found that kidney volume in PKD does not correlate with patient's IPP (9).

The IPP correlated negatively to serum creatinine: the higher the serum creatinine, the lower the IPP. Few studies have documented these parameters, which is why we have failed to find any precedents to these results. Serum creatinine is a nutritional marker and an indirect marker of the PD patient's muscular mass. Two studies that use serum creatinine as a body composition marker in patients on PD have found that patients with a high BMI and greater excretion of creatinine in urine present a greater survival rate (40,41). IPP may be related to the patients' nutritional status, however these results should be analysed with caution.

The presence of hernia in PD were associated with low D/P creatinine. We have not found any reference in the literature. In our study a low D/P creatinine was associated with women and a history of PQR. In addition, patients with a low D/P creatinine have increased ultrafiltration in PD and higher IPV, both conditions could explain this relationship.

Finally, we must highlight the fact that multiparous females have a higher IPP which increases in cases of over three pregnancies. This has only been analysed in one study where the authors failed to find any relationship with IPP (9). This was the first study that related multiparity with a high IPP in PD. This finding is of great interest and should be validated.

Limitations: No repeated IPP measurements were taken periodically in the follow-up. Factors that may modify IPP such as previous prior food intake, bladder volume and constipation, were not taken into account.

Conclusions: The present study is the first to show that high IPP at PD onset is related to the development of hernias in PD in a statistically significant way. Other factors have been found to be involved in their development, namely BMI, older age, a history of prior hernia and catheter placement by laparoscopy. The presence of hernias in PD was significantly related to technique failure.

BMI is still the factor that has the greatest influence on high IPP, but other factors such as older age, greater comorbidity, mulitiparity, and a history of DM are also involved. Measurement of IPP in adult PD is recommended, as it may help us to prevent complications in the abdominal wall.

References

1. Al-Hwiesh A, Al-Mueilo S, Saeed I, Al-Muhanna FA. Intraperitoneal pressure and intra-abdominal pressure: Are they the same? Perit Dial Int. 2011;31(3):315–9.
2. Durand PY, Chanliau J, Gamberoni J, Hestin D, Kessler M. Routine measurement of hydrostatic intraperitoneal pressure. Adv Perit Dial. 1992;8(3):108–12.
3. Sobrino-Pérez A, Pérez-Escudero A, Fernández-Arroyo L, Dorado-García A, Martín-Alcón B, Gutiérrez-Martín C, et al. Intraperitoneal pressure: Stability over time and validation of Durand's measurement method. Perit Dial Int. 2021;41(4):427–31.
4. Dejardin A, Robert A, Goffin E. Intraperitoneal pressure in PD patients: Relationship to intraperitoneal volume, body size and PD-related complications. Nephrol Dial Transplant. 2007;22(5):1437–44.
5. Outerelo MC, Gouveia R, Teixeira F RA. Intraperitoneal Pressure Has a Prognostic Impact on Peritoneal Dialysis Patients. 2014;34:652–4.
6. Castellanos LB, Clemente EP, Cabañas CB, Parra DM, Contador MB, Morera JCO, et al. Clinical relevance of intraperitoneal pressure in peritoneal dialysis patients. Perit Dial Int. 2017;37(5):562–7.
7. Scanziani R, Dozio B, Baragetti I, Maroni S. Intraperitoneal hydrostatic pressure and flow characteristics of peritoneal catheters in automated peritoneal dialysis. Nephrol Dial Transplant. 2003;18(11):2391–8.
8. Giuliani A, Milan Manani S, Crepaldi C, Domenici A, Gastaldon F, Corradi V, et al. Intraperitoneal Pressure in Polycystic and Non-Polycystic Kidney Disease Patients, Treated by Peritoneal Dialysis. Blood Purif. 2020;49(6):670–6.
9. Sigogne M, Kanagaratnam L, Mora C, Pierre M, Petrache A, Marcus C, et al. Identification of the Factors Associated With Intraperitoneal Pressure in ADPKD Patients Treated With Peritoneal Dialysis. Kidney Int Reports [Internet]. 2020;5(7):1007–13. Available from: https://doi.org/10.1016/j.ekir.2020.04.012
10. Pérez Díaz V, Sanz Ballesteros S, Hernández García E, Descalzo Casado E, Herguedas Callejo I, Ferrer Perales C. Intraperitoneal pressure in peritoneal dialysis. Vol. 37, Nefrologia. 2017. p. 579–86.
11. Twardowski ZJ, Khanna R, Nolph KD, Scalamogna A, Metzler MH, Schneider TW, et al. Intraabdominal Pressures during Natural Activities in Patients Treated with Continuous Ambulatory Peritoneal Dialysis. Nephron [Internet]. 1986;44(2):129–35. Available from: https://www.karger.com/Article/FullText/184217
12. Aranda RA, Romão JE, Kakehashi E, Domingos W, Sabbaga E, Marcondes M, et al. Intraperitoneal pressure and hernias in children on peritoneal dialysis. Pediatr Nephrol. 2000;14(1):22–4.
13. Fischbach M, Zaloszyc A, Schaefer B, Schmitt CP. Optimizing peritoneal dialysis prescription for volume control: The importance of varying dwell time and dwell volume. Pediatr Nephrol. 2014;29(8):1321–7.
14. Morelle J, Stachowska-Pietka J, Öberg C, Gadola L, La Milia V, Yu Z, et al. ISPD recommendations for the evaluation of peritoneal membrane dysfunction in adults: Classification, measurement, interpretation and rationale for intervention. Perit Dial Int. 2021;41(4):352–72.

15. Pierre Yves Durand, Jacques Chanliau, Joel Gamberoni, Dominique Hestin MK. APD: clinical measurement of the maximal acceptable intraperitoneal volume. Perit Dial Int. 1994;10:63–7.
16. Gotloib L, Mines M, Garmizo L, Varka I. Hemodynamic effects of increasing intraabdominal pressure in peritoneal dialysis. Perit Dial Int. 1981;1:41–3.
17. Gotloib L, Garmizo L, Mines M. Reduction of vital capacity due to increased intra-abdominal pressure during peritoneal dialysis. Perit Dial Int. 1981;1:63–4.
18. Fischbach M, Terzic J, Provot E, Weiss L, Bergere V, Menouer S SK. Intraperitoneal Pressure in children: FiLL- volume related and impacted by body mass index [Internet]. Peritoneal Dialysis International; 2003. p. 391–4. Available from: papers2://publication/uuid/CC49FA83-CCC9-47EE-BA8F-4A89C5B58B55
19. Pérez-Díaz V, Pérez-Escudero A, Sanz-Ballesteros S, Sánchez-García L, Hernández-García E, Oviedo-Gómez V, et al. Clinical relevance of marginal factors on ultrafiltration in peritoneal dialysis. Perit Dial Int. 2021;41(1):86–95.
20. Cho Y, See EJ, Htay H, Hawley CM, Johnson DW. Early peritoneal dialysis technique failure: Review. Perit Dial Int. 2018;38(5):319–27.
21. Engeset J, Youngson GG. Ambulatory peritoneal dialysis and hernial complications. Surg Clin North Am [Internet]. 1984;64(2):385–92. Available from: http://dx.doi.org/10.1016/S0039-6109(16)43292-5
22. O'Connor JP, Rigby RJ, Hardie IR, Wall DR, Strong RW, Woodruff PWH, et al. Abdominal hernias complicating continuous ambulatory peritoneal dialysis. Am J Nephrol. 1986;6(4):271–4.
23. Del Peso G, Bajo MA, Costero O, Hevia C, Gill F, Díaz C, et al. Risk factors for abdominal wall complications in peritoneal dialysis patients. Perit Dial Int. 2003;23(3):249–54.
24. Gracia Toledo M, Borràs Sans M, Gabarrell A, Durán J, Fernández Giráldez E. Factores de riesgo para desarrollar hernias abdominales en enfermos en diálisis peritoneal. Nefrologia. p. 218–9.
25. Afthentopoulos IE, Panduranga Rao S, Mathews R OD. Hernia development in CAPD patients and the effect of 2.5 l dialysate volume in selected patients. Clin Nephron. 1998;49(4):251–7.
26. Burke KA, Mather PT. Crosslinkable liquid crystalline copolymers with variable isotropization temperature. J Mater Chem. 2012;22(29):14518–30.
27. Wetherington GM, Leapman SB, Robison RJ, Filo RS. Abdominal wall and inguinal hernias in continuous ambulatory peritoneal dialysis patients. Am J Surg. 1985;150(3):357–60.
28. Martinez-Mier G, Garcia-Almazan E, Reyes-Devesa HE, Garcia-Garcia V, Cano-Gutierrez S, Mora Y Fermin R, et al. Abdominal wall hernias in end-stage renal disease patients on peritoneal dialysis. Perit Dial Int. 2008;28(4):391–6.
29. Crabtree JH, Shrestha BM, Chow K-M, Figueiredo AE, Povlsen J V., Wilkie M, et al. Creating and Maintaining Optimal Peritoneal Dialysis Access in the Adult Patient: 2019 Update. Perit Dial Int J Int Soc Perit Dial 2019 Sep 1;39(5):414–36.
30. Morris-Stiff G, Coles G, Moore R, Jurewicz A, Lord R. Abdominal wall

hernia in autosomal dominant polycystic kidney disease. Br J Surg. 1997;84(5):615–7.
31. Li L, Szeto CC, Kwan BCH, Chow KM, Leung CB, Kam-Tao Li P. Peritoneal dialysis as the first-line renal replacement therapy in patients with autosomal dominant polycystic kidney disease. Am J Kidney Dis. 2011;57(6):903–7.
32. Dupont V, Kanagaratnam L, Sigogne M, Bechade C, Lobbedez T, Portoles J, et al. Outcome of polycystic kidney disease patients on peritoneal dialysis: Systematic review of literature and meta-analysis. PLoS One. 2018;13(5):1–12.
33. Tokgoz B, Dogukan A, Guven M, Unluhizarci K, Oymak O, Utas C. Relationship between different body size indicators and hernia development in CAPD patients. Clin Nephrol [Internet]. 2003;60(3):183–6. Available from: http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med4&NEWS=N&AN=14524581
34. Van Dijk CMA, Ledesma SG, Teitelbaum I. Patient characteristics associated with defects of the peritoneal cavity boundary. Perit Dial Int [Internet]. 2005 Jan 1 [cited 2018 Nov 15];25(4):367–73. Available from: http://www.ncbi.nlm.nih.gov/pubmed/16022094
35. Mahase AS, Katyal A KR. complications of peritoneal dialysis related to increased intra-abdominal pressure. Adv peritoenal Dial. 2003;19:130–5.
36. Mahale AS, Katyal A, Khanna R. Complications of peritoneal dialysis related to increased intra-abdominal pressure. Adv Perit Dial. 2003;19:130–5.
37. Leblanc M, Ouimet D P, V. Dialysate leaks in peritoneal dialysis. Semin Dial. 2001;14:50–4.
38. Hirsch DJ JK. late leaks in peritoneal dialysis patients. Nephrol Dial Transplant. 1990;6:670–1.
39. Albaz M, Kantarci G, Tuglular S, Tercüman N, Tetik G, Özener C. Causes of late leaks in peritoneal dialysis patients. EDTNA-ERCA J. 2002;28(4):170–2.
40. Beddhu S, Pappas LM, Ramkumar N, Samore M. Effects of body size and body composition on survival in hemodialysis patients. J Am Soc Nephrol. 2003;14(9):2366–72.
41. Nirupama Ramkumar , Lisa M Pappas SB. Effect of body size and body composition on survival in peritoneal dialysis patients. Perit Dial Int. 200AD;25(5):435–7.

Variable	N (*n*=124)
Demographics	
Age (years)	62.1±15.23
Gender men *n* (%)	85 (68.5)
BMI (kg/m^2)	27.7±4.82
Comorbidities	
Charlson Comorbidity Index	4.8±1.92
Diabetes Mellitus *n* (%)	54 (43.5)
Cause of renal Disease (DM/HTA) *n* (%)	76 (61.3)
History of prior hernia *n* (%)	11 (8.9)
History of PKD *n* (%)	5 (4.0)
History of abdominal surgery *n* (%)	17 (13.7)
Variables related to PD	
CAPD *n* (%)	76 (61.2)
Icodextran use *n* (%)	85 (68.5)
IPV day (mL)	1527.8±798.06
IPV night (mL)	2064.8±220.85
Urine volume (mL)	1367.8±781.01
IPP supine position (cm H_2O)	16.6±4.60
IPP upright position (cm H_2O)	27.8±5.22
IPV (IPP) (mL)	2047.1±359.19
Hernias in PD *n* (%)	23 (18.5)
Peritoneal Leaks *n* (%)	25 (20.1)

Table 1: Patient Characteristics

BMI= body mass index; DM= Diabetes Mellitus; HTA = Arterial hypertension; PKD= polycystic kidney disease; CAPD= continuous ambulatory peritoneal dialysis; IPV = intraperitoneal volume; IPP= intraperitoneal pressure. PD= peritoneal dialysis.

Variable	With Hernias (N=23)	Without Hernias (N=101)	P
Age (years)	67.6±9.02	60.9±16.10	0.008
Men/women *n* (%)	18 (21.2) / 5 (12.8)	67 (78.8) / 34 (87.2)	0.266
Diabetes mellitus (Si/No) *n* (%)	9 (16.4) / 14 (20.3)	46(83.6) / 55(79.7)	0.576
History of previous hernia (Si / No) *n* (%)	5 (45.5) / 18 (15.9)	6(54.5) / 95(84.1)	0.016
History of PKD (Si/No) *n* (%)	2 (40) / 21 (17)	3(60.0) / 98(82.4)	0.208
Pregnancy (Si /No) *n* (%)	5 (16.7) / 0 (0)	25 (83.3) / 9(100)	0.190
BMI (kg/m^2)	29.5±5.36	27.3±4.67	0.043
Serum creatinine (mg/dL)	6.8±2.15	6.7±2.54	0.851
Charlson Comorbidity Index	5.1±2.38	4.7±1.86	0.392
IPP supine position (cm H_2O)	18.4±4.58	16.2±4.52	0.037
IPP upright position (cm H_2O)	29.7±5.04	27.3±5.19	0.071
PD catheter insertion *n* (%) Laparoscopy Percutaneous (Y-TEC) Percutaneous (Seldinger)	11 (30.6) 9 (20.0) 3 (7.0)	25 (69.4) 36 (80.0) 40 (93.0)	0.026
CAPD/APD *n* (%)	13 (16.5) /10 (22.2)	66 (83.5) / 35 (77.8)	0.427
Peritoneal Leaks (Si/ No) *n* (%)	8 (32.0) / 15(15.2)	17 (68.0) / 84 (84.8)	0.053
Peritonitis (Si/No) *n* (%)	13 (25.0) / 10 (15.5)	30 (75.0) / 71 (84.5)	0.202
Death /Transfer to HD (Si/No) *n* (%)	15 (28.8) / 8 (11.5)	37 (71.2) / 64 (88.5)	0.012

Table 2: Comparative Characteristics of patient with and without hernias.
PKD = polycystic kidney disease; BMI = body mass index; PD = peritoneal dialysis; IPP = intraperitoneal pressure; CAPD = continuous ambulatory peritoneal dialysis; APD = Automatic peritoneal dialysis; HD = haemodialysis.

	Odds Ratio	95% Confidence Interval	*P* Value
D/P creatinine	0.003	(0.000 to 0.649)	0.034
IPP	1.131	(1.014 to 1.262)	0.028

Table 3: Risk factor for Hernias Development.
Multivariate model. IPP = intraperitoneal pressure.

Variable	Estimated value β	R	P
Age (years)	0.088	0.290	0.001
BMI (kg/m^2)	0.538	0.569	<0.001
Serum Creatinine (mg/dL)	-0.143	0.21	0.019
Creatinine Clearance (mL/minute)	0.187	0.217	0.019
Charlson Comorbidity Index	0.803	0.344	<0.001
IPV day (mL)	-0.001	0.113	0.216
IPV night (mL)	-7.515	0.058	0.523
IPV (IPP) (mL)	0.001	0.110	0.222
Urine volume (mL)	0.001	0.214	0.017

Table 4: Risk factor for High IPP
Univariate model. BMI= body mass index; IPV = intraperitoneal volume; IPP= intraperitoneal pressure.

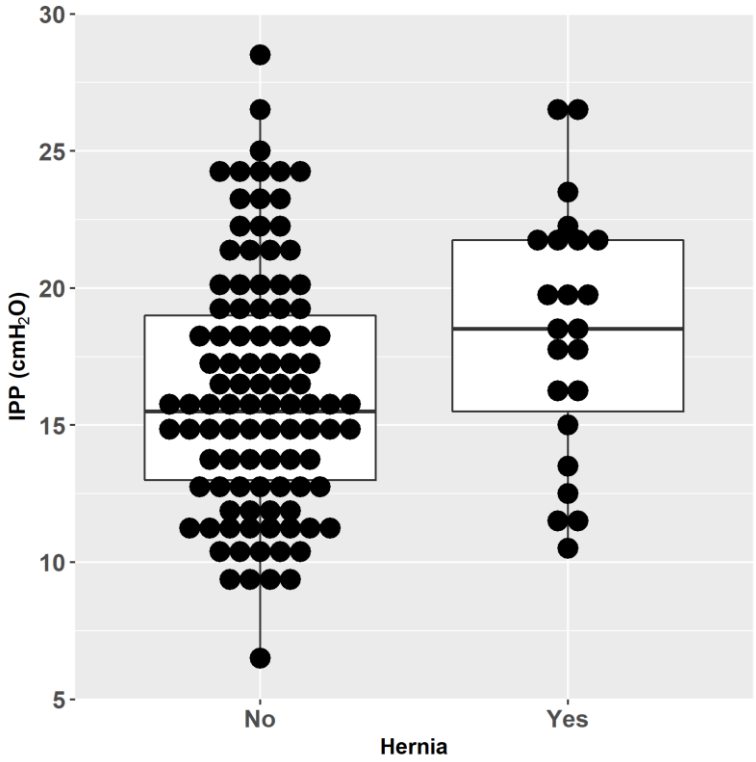

Fig 1: IPP and development of hernias in PD.
IPP= intraperitoneal pressure.

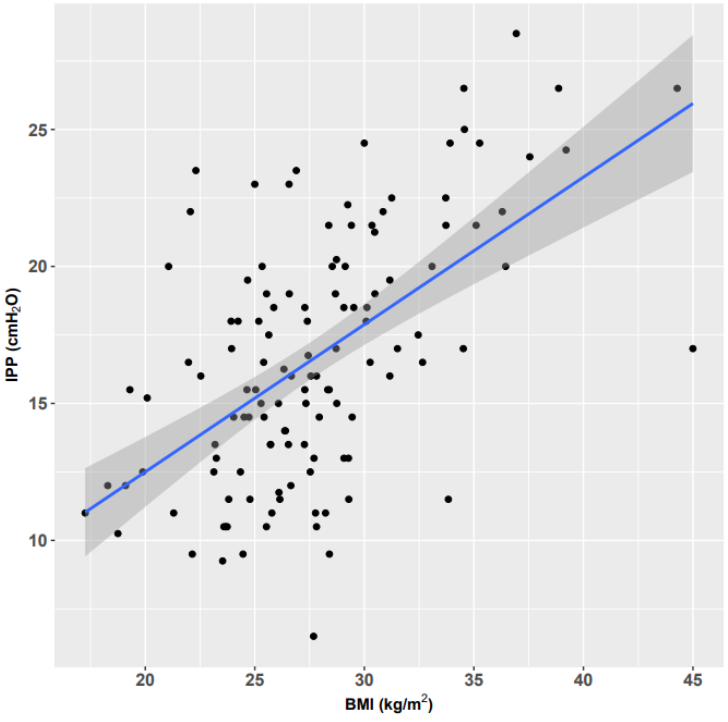

Figure 2: Positive correlation between IPP and BMI.
BMI= body mass index; IPP= intraperitoneal pressure.