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# Peritoneal dialysis in children: Pathophysiological approaches, prescription and management of complications for adequate treatment

Dialyse péritonéale chez l'enfant :
Approches physiopathologiques, prescription et gestion des complications pour un traitement adéquat

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## Summary

Peritoneal dialysis (PD) is the most commonly used renal replacement therapy in children worldwide. It utilizes the peritoneal membrane as a semi-permeable surface for the exchange of solutes and water between the dialysate and peritoneal capillaries. There are two main modalities: continuous ambulatory peritoneal dialysis (CAPD) and automated peritoneal dialysis (APD), the latter being performed at home using a cycler.

Pediatric prescriptions must be individualized based on body surface area, intraperitoneal pressure (IPP), and specific dialysis needsPD is generally well tolerated and offers several advantages, such as better preservation of residual diuresis, the possibility of home-based treatment, and the continuity of schooling. It also doesn't require anticoagulation. However, it may lead to mechanical complications (hernias, leaks, pain) and infectious ones (peritonitis, catheter-related infections),some times more frequent than in adults.

Placement of an appropriate catheter (e.g., Tenckhoff) under sterile conditions with antibiotic prophylaxis is crucial for effective and safe treatment. The adequation of dialysis take into acount the choice of dialysis solution (glucose, icodextrin, bicarbonate or lactate buffer) and prescription parameters (volume, dwell time, number of cycles) should aim to optimize clearance while preserving peritoneal membrane function, but also maintain normal child weight and height growth. PD is the technique of choice in pediatrics, PD remains a flexible, effective, and suitable alternative, especially for young children or when access to hemodialysis is limited.

## Résumé

La dialyse péritonéale (DP) est la modalité de suppléance rénale la plus utilisée chez l'enfant dans le monde. Elle utilise la membrane péritonéale comme surface d'échange semi perméable pour les échanges d'eau et de solutés entre le dialysat et les capillaires péritonéaux. Deux techniques principales sont proposées: la dialyse péritonéale continue ambulatoire (DPCA) et la dialyse péritonéale automatisée (DPA).

La prescription pédiatrique doit être individualisée en fonction de la surface corporelle, de la pression intra-péritonéale (PIP) et des besoins spécifiques en dialyse. La DP est généralement bien tolérée et présente plusieurs avantages : une meilleure préservation de la fonction rénale résiduelle, une possibilité de traitement à domicile, un maintien de la scolarité, et l'absence d'anticoagulation. Elle peut toutefois entraîner des complications mécaniques (hernie, fuite, douleurs) et infectieuses (péritonites, infections liées au cathéter) parfois plus fréquentes que chez les adultes.

La pose d'un cathéter adapté (type Tenckhoff) dans des conditions stériles, associée à une prophylaxie antibiotique, est essentielle pour garantir l'efficacité et la sécurité du traitement. L'adéquation de la dialyse en pédiatrie tient compte du choix du soluté (glucose icodextrine, bicarbonate ou lactate), des paramètres de la prescription pour optimiser clearances et volumes, tout en préservant la membrane péritonéale, .mais a également pour but de maintenir la croissance staturo-pondérale normale de l'enfant. La dialyse péritonéale est la technique d'épuration extrarénale de choix pour les enfants d'autant plus pour ceux qui habitent loin des centres d'hémodialyse pédiatrique.

**Keywords** : peritoneal dialysis, paediatrics, dialysis prescription, advantages and disadvantages, renal failure

**Mots-clés** : Dialyse péritonéale, pédiatrie, prescription dialyse, avantages et inconvénients, insuffisance rénale





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## INTRODUCTION

Peritoneal dialysis (PD) is the most widely used extra-renal replacement therapy in children worldwide, particularly in younger children and in low- and middle-income countries [1].
In Europe, PD is the initial treatment modality for stage 5 Chronic Kidney Disease (CKD) in 40% of cases, according to the ESPN/ERA-EDTA registry. The principle of PD lies in the use of the peritoneal membrane as a filter membrane [2].

## THE PERITONEUM

The peritoneum is a membrane made up of two layers: the parietal layer and the visceral layer, which are joined by the mesos. The peritoneal membrane is made up of mesothelium, interstitium, and capillaries (*Figure 1*).

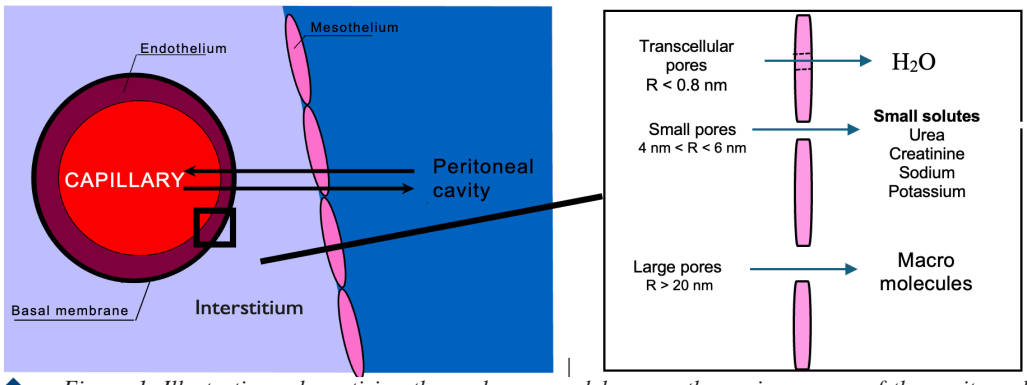


*Figure 1. Illustration schematizing the exchange model across the various pores of the peritoneal membrane according to Rippe B.*
*Ultra-small pores (transcellular transport via type 1 aquaporins) are mainly responsible for osmotic gradient-mediated free water transport (usually glucose), playing a vital role at the start of the cycle, when the crystalloid gradient is strong. They are responsible for 40–50% of ultrafiltration (UF). Small pores transfer water by diffusion and convection (50–60% of overall UF), as well as water coupled with solutes (urea, creatinine, sodium, etc.). Large pores allow macromolecules to pass through.*
*H2O: water, R: radius, nm: nanometer*

The peritoneal cavity is the space between the two sheets. Under physiological conditions, this "virtual" space contains less than 100 mL of a liquid formed from plasma ultrafiltrate. This effluent contains few cells (fewer than 50 cells/mL) and no neutrophils in the absence of infection [3]. This is a "functional" anatomical contact and exchange surface measuring 0.5 to 2 m2 [4]. In children, the prescription of peritoneal dialysis must be individually adapted, taking into account the body surface area (expressed in mL/m²) to determine the intraperitoneal filling volume (IPF). In fact, anatomical peritoneal surface area is age-invariant if expressed per unit of body surface area [5,6].

### PD exchange principle

During PD in both adults and children, the capillaries of the peritoneal surface are recruited (only 20% are perfused at rest). The abdominal pressure resulting from dialysate infusion is known as

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ISSN 2607-9917

intraperitoneal pressure (IPP). Transperitoneal exchanges take place via several mechanisms, with the peritoneal membrane behaving like a semi-permeable membrane; it allows diffusion, absorption, and convection.

A mathematical model with three pore types, proposed by B. Rippe, models the transports established during PD [7]. The histological equivalent of small and large pores has not been established. This model is illustrated in Figure 1.

## INDICATIONS AND CONTRAINDICATIONS FOR PD IN CHILDREN

It is recommended to start a replacement technique in children with an estimated glomerular filtration rate (eGFR) of less than 10 mL/min/1.73 m2, or when the child presents uremic symptoms refractory to medical treatment [2]. PD is then the technique of choice, particularly in infants, due to the absence of appropriate extra body circuits dedicated to them in chronic hemodialysis [8]. PD can be used from birth, including in premature infants [9].

However, no study has shown that one dialysis modality is superior to another in terms of survival [10]. Thus, the choice of dialysis modality depends on the convictions and possibilities of the teams in charge of the child and the choice of the family.

### Advantages of PD

This is a gentle, physiological dialysis method that ensures good hemodynamic tolerance and preserves residual diuresis. Unlike hemodialysis, it does not require anticoagulation. PD also helps to maintain vascular capital, an essential factor in these young patients, who are likely to undergo several renal replacement therapies over the course of their lives. PD is carried out at home, which limits "hospital constraints." This technique is also preferable when the family is far from the dialysis center. Nocturnal PD enables schooling to be maintained. Compared with non-intensive hemodialysis techniques, daily PD also reduces water restriction and dietary constraints. In order to optimize staturo-weight growth in children with chronic renal failure, enteral nutritional support is often necessary to cover the caloric needs required according to the child's age [11]. In addition, children with chronic renal failure are treated with daily injections of growth hormone to optimize statural growth [12].

### Disadvantages of PD

The technique can nevertheless represent a significant burden for the family, leading to difficulties with adherence in adolescents who may find the dialysis time too long. Studies on the quality of life of families of children undergoing peritoneal dialysis highlight a significant impact on their well-being [13], with a high prevalence of anxiety-depressive disorders among parents [14]. Chronic PD also leads to alterations in the peritoneal membrane. Chronic PD induces submesothelial fibrosis and neoangiogenesis, clinically reflected in altered membrane transport [15].

PD is contraindicated in children with pathologies that affect the integrity of the peritoneal membrane or cavity, such as omphalocele, bladder exstrophy, diaphragmatic hernia, laparoschisis, or obliterated peritoneal cavity. The presence of ileostomies and colostomies, significant organomegaly, living situations unsuitable for home dialysis, lack of appropriate caregiver

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support, and recent abdominal surgery may lead to discussion of the first-line indication for PD [16].

## PRESCRIBING PD IN PRACTICE

There are several stages in the process once the indication for PD has been established, the family's commitment to the project has been ascertained, and the feasibility of the procedure has been verified.

The practitioner will first select the catheter and ensure that it is in place and functioning properly. The PD modality will then be chosen, proposing either automated peritoneal dialysis (APD) or continuous ambulatory peritoneal dialysis (CAPD). The prescriber will start dialysis by gradually increasing the intraperitoneal volume, determining the optimal contact time and the right dialysate, and individualizing the prescription to suit the patient's dialytic needs and optimizing purification. Therapeutic education will be provided for the family to enable them to become autonomous in their care and return home safely.

### PD catheters

A dialysis catheter is inserted surgically by endoscopic technique, laparotomy, or percutaneously into the abdominal wall. Available studies do not allow determination of which catheter insertion technique in peritoneal dialysis offers the best clinical results, although surgical insertion is recommended [17,18].

The positioning of the catheter is a decisive factor in ensuring quality dialysis. The catheter consists of three parts *(Figure 2)*: an intra-abdominal part, a subcutaneous part anchored by cuffs, and an external part. The catheter most commonly used in pediatrics is the Tenckhoff type with one or two cuffs, which is said to be associated with lower infectious and mechanical risks [19].

The intra-abdominal tip is placed at the level of the cul-de-sac of Douglas, the most sloping part of the peritoneal cavity, to ensure good drainage. In children, the length of the intra-abdominal segment is adapted to their morphology, and the size of the catheter is chosen according to the distance between the navel and the symphysis pubis of each child (the total length of these Tenckhoff-type catheters is 31, 38.9, 59, or 62.5 cm). The intra-abdominal tip is straight or spiral-shaped, with orifices for dialysate passage. The subcutaneous end is straight or swan-necked.

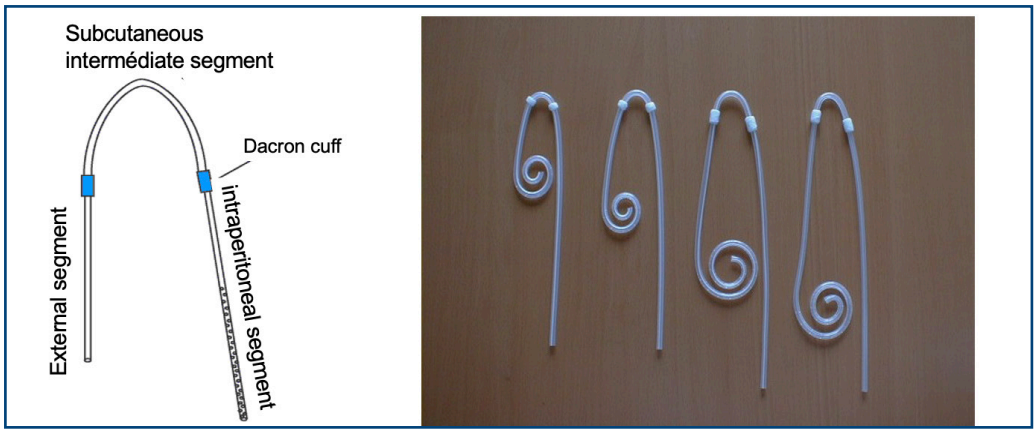


*Figure 2. Diagram and photo of the different sizes of Tenckhoff catheters used in pediatrics*

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The catheter is preferably placed at a distance from stomas on the left side (except in the case of stomas) to leave the right iliac fossa free in the case of kidney transplants and to follow the direction of intestinal peristalsis to limit catheter displacement. Catheter emergence is lateral or cranial when cleanliness has not yet been acquired, and caudal in other cases.

The catheter should be inserted at least 2 weeks before the planned start of PD, whenever clinically feasible, to promote healing, limit catheter displacement, and minimize dialysate leakage. If the dressing is not soiled, it should not be re-dressed until a week later. Catheter insertion must be accompanied by antibiotic prophylaxis to prevent the risk of dialysis fluid infection [20]. The new recommendations published in 2024 recommend cefazolin as the first choice (25 mg/kg, maximum 2 g), a dose to be administered one hour before surgery, or vancomycin in the case of resistant germs [18].

To avoid infection of the dialysis catheter emergence in pediatrics, frequent cleaning after careful hand washing and inspection of the exit point must be carried out rigorously, as the main causes of catheter loss are infection and obstruction. A rating score for catheter emergence frequently used in pediatrics is detailed in *Table 1* [21]. Sterile dressing is recommended two to three times a week and after exposure to water or soiling of the dressing [22].

| | 0 | 1 | 2 |
|---|---|---|---|
| **Erythema** | No | <0.5 cm | >0.5 cm |
| **Tenderness** | No | moderate | severe |
| **Oedema** | No | <0.5 cm | >0.5 cm and/or of tunnel |
| **Crusting** | No | <0.5 cm | >0.5 cm |
| **Discharge** | No | serous | purulent |

*Table 1: Peritoneal dialysis catheter emergence score (cm: centimeter).*

## Dialysis cycle, prescription procedures

***Continuous ambulatory peritoneal dialysis (CAPD) treatment***

CAPD is the most widely used dialysis technique in the world due to its simplicity and low cost, although it is not the technique of choice in France. With this techniquen no cycler is used. The dialysate in a bag suspended from a gallows is infused into the patient, who disconnects during the stasis phase and reconnects for the drainage phase (*Figure 3*)

In pediatrics, the child benefits from four to six cycles a day, usually performed by the parents, which means that the parents must be involved throughout the 24 hours. This dialysis method is ill-suited to individualized prescriptions. It requires a small number of daily cycles, with long stasis times, which limits UF in

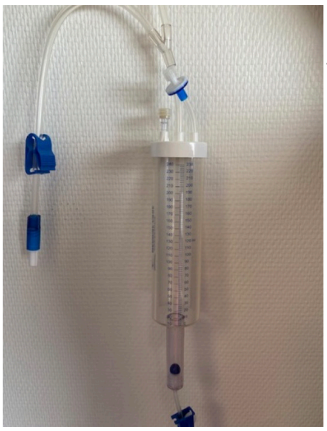

*Figure 3. The PD-Paed Plus system from Fresenius medical care*
*The PD-Paed Plus system is a graduated tubing system for up to 200 mL in a pre-assembled kit, enabling small volumes to be infused and drained with precision, thanks to the combination of infusion and drainage burettes, enabling PD for neonates and infants.*

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general but improves sodium and phosphate extraction. In addition, dialysis performed in the orthostatic position leads to the prescription of smaller intraperitoneal volumes due to poorer tolerance than in the supine position, in conjunction with increased IPP. Finally, we must also take into account the risk of infection secondary to repeated manipulations and the constraints this implies for the child and their parents. It should be noted that CAPD can also be performed on newborns, notably with the use of very small volumes, via the burette system (not currently available on a retrocedible basis).

***Automated peritoneal dialysis (APD) treatment***

APD uses a machine called a cycler. Dialysis is carried out at home, during the night, possibly leaving the patient with daytime stasis. The session generally lasts 8 to 11 hours, depending on the child's needs and constraints (schooling), with several consecutive cycles. There are several types of APD, detailed in *Figure 4* below.

Intermittent PD consists of several consecutive overnight cycles. Continuous cyclic PD (CCPD) involves a nocturnal session, plus a long daytime stasis (icodextrin or glucose-based solutions) after the last overnight injection. Fluctuating PD involves several partial drainages, as well as complete drainage after a certain number of cycles. Lastly, adapted PD makes it possible to vary times and volumes during a dialysis session, thereby increasing UF and sodium extraction while maintaining the same total dialysate volume and overall dialysis time [23]. In practice, adapted APD is often prescribed in the form of a repeated alternation of a short cycle followed by a long cycle.

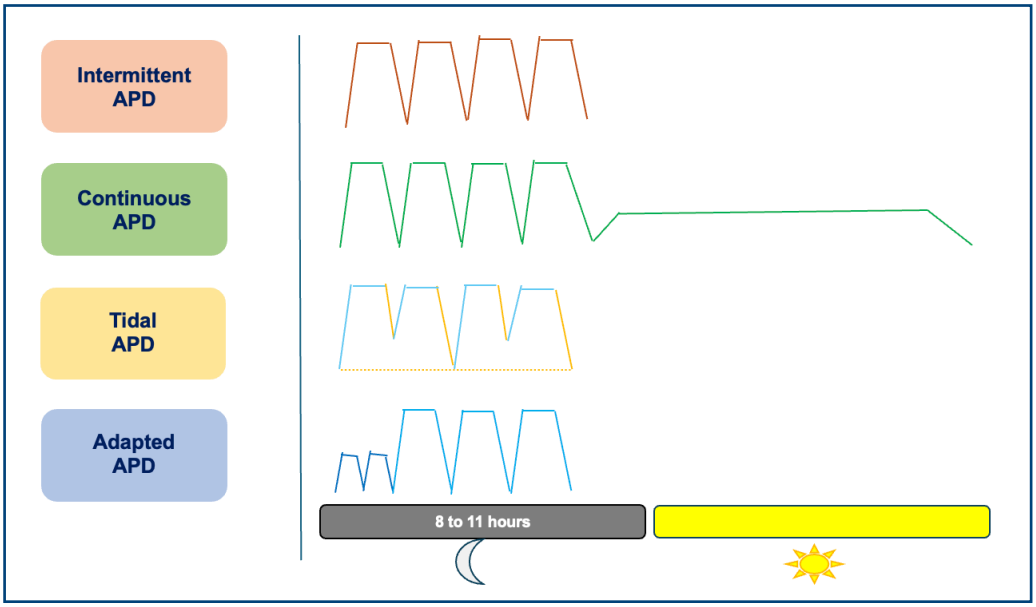


*Figure 4. Diagram illustrating the different APD prescriptions on a cycler*

## Main principles of dialysis prescription in children

### Prescribing dialysate

Dialysate is a sterile solution of water, buffer, and osmotic agent. Isotonic dialysate (1.5% glucose concentration) is most often used. A hypertonic solution is used when it is necessary to increase the UF. Dialysates will eventually lead to alteration of the peritoneal membrane,



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and excessive use of hypertonic dialysate, lactate buffers, and non-biocompatible solutions will increase this alteration. It is therefore preferable to use a biocompatible dialysate in children whenever possible (not always available in all countries), with a neutral pH and a bicarbonate buffer to preserve the peritoneal membrane. The use of a dialysate containing icodextrin enables UF to be preserved during long stasis (diurnal stasis).

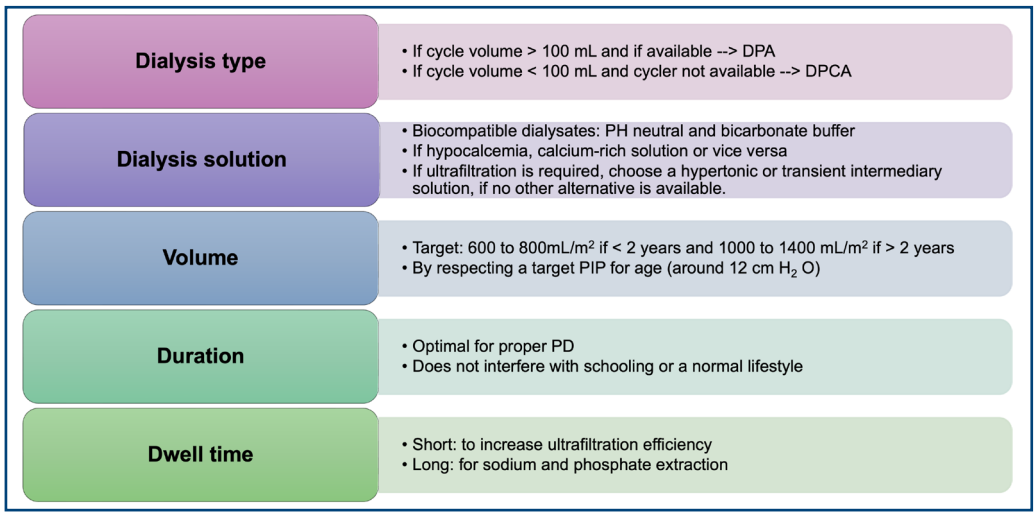


*Figure 5. Outline diagram for a PD prescription*
*APD: automated peritoneal dialysis, CAPD: continuous ambulatory peritoneal dialysis, mL: milliliter, m2: square meter, IPP: intraperitoneal pressure*

Stasis time plays an important role in the effectiveness of prescribed exchanges. Purification depends on the length of the cycle: the longer the stasis time, the better the purification, since it gives time for exchanges to take place, particularly for "large" molecules such as phosphate. Too long a stasis time will result in a reduction in UF due to loss of the dialysate's osmotic power (glucose reabsorption). A short stasis time will conserve UF but will result in less purification. The definition of optimal times depends on individual characteristics, as revealed by PET test of the peritoneal membrane [24]. PET can be used to assess urea saturation and glucose desaturation levels in the dialysate. The area under the curve, which crosses the saturation and desaturation rates, defines the APEX (Accelerated Peritoneal Equilibration eXamination) time [25]. This time theoretically defines an optimum contact time to ensure optimal UF and urea purification for a defined intraperitoneal volume [26]. The figure 5 summarizes these outlines for a PD prescription.

The intraperitoneal volume is prescribed according to the child's body surface area. It is gradually increased to avoid dialysate leakage and improve dialysis tolerance. The volume prescribed is generally 30–50 mL/kg or 600–800 mL/m2 for children under 2 years of age, and from 1,000 to 1,200–1,400 mL/m2 for children over 2 years of age [5]. A large volume leads to greater capillary recruitment and better purification. However, too large a volume can lead to patient discomfort and retrofiltration.

In CAPD, "effective" volumes are between 900 and 1,100 mL/m2 . Daytime volumes are lower than night-time volumes (around 800–1,000 mL/m2 vs. 1,000–1,400 mL/m2) to avoid mechanical complications. IPP measurement is a valuable aid in determining maximum peritoneal volume. Under no circumstances should the IPP exceed 18 cm H2O, as this would expose the child to mechanical complications (hernia, respiratory difficulties, etc.). In practice, the acceptable IPP is 12 to 14 cm H2O for children over 2 years of age, and 8 to 10 cm for children under 2.

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## COMPLICATIONS OF PERITONEAL DIALYSIS

### Non infectious complications

*Mechanical complications*

As with adults, hernias are the most frequent "mechanical" complications in PD, especially so in younger children, as the peritoneovaginal canal persists until the age of 2 [27]. Peritoneal dialysis catheter malfunction may be secondary to catheter displacement, kinking, or obstruction. Depending on the etiology, laxative treatment, surgical repositioning of the catheter, or fibrinolytic therapy may be suggested.

Dialysate leakage around the catheter or into the abdominal wall occurs more frequently in children weighing less than 10 kg [28]. The use of large volumes of dialysate within 2 weeks of catheter insertion is a contributing factor. Extrusion of a catheter sleeve is a frequent complication that can lead to local inflammation and increase the risk of infection.

Other rarer mechanical complications include hydrothorax, hemoperitoneum, pneumoperitoneum, or chyloperitoneum [29,30]. Abdominal pain at the time of infusion is more frequent with acid PH dialysates buffered by lactate [31].

Pain during drainage may be secondary to the fact that the chosen catheter is long or poorly positioned, inducing a sensation of heaviness and pelvic irritation. Pain during the drainage phase is more frequent in APD than in CAPD due to the hydrostatic pressure induced by the cycler at the start of the drainage phase. Infusion and drainage speed must be optimized according to age when prescribing limits on the cycler software [32].

### Infectious complications

Infectious complications are common in children, and even more so in infants [33].

- Exit site infection and tunnelitis

Tunnelitis is defined by the presence of redness, swelling, and tenderness along the subcutaneous path of the catheter. Catheter emergence infection is defined by the presence of a purulent discharge at the catheter-skin interface [34]. Staphylococci are responsible for the majority of catheter emergence infections, followed by Pseudomonas aeruginosa. Risk factors associated with a higher incidence of catheter infection are poor local care, catheter compression, bathing, the presence of animals (especially during dialysis hook-up), and poor catheter handling. Thus, therapeutic education of the family is crucial to avoid these infections.

In order to prevent and treat catheter-related infections more effectively, new recommendations were issued in 2024 [18]. They reiterate the main principles of asepsis: antibiotic prophylaxis should be administered at the time of catheter insertion, and careful catheter care should be practiced. As no antiseptic solution has been shown to be superiorly effective in preventing catheter-related infections, the application of an antibiotic (mupirocin) to the exit port may be suggested. In the event of infection, the dressing should be changed daily. Nasal carriage of Staphylococcus aureus

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should be treated with mupirocin. The choice, duration, and route of antibiotic administration will be adapted on a case-by-case basis, in line with new recommendations.

- Peritonitis

Peritoneal fluid infection is the main complication of PD and may lead to the technique being abandoned if episodes are repeated. It is a diagnostic and therapeutic emergency. Signs suggestive of peritonitis include cloudy drainage fluid and/or pain and/or difficulty infusing and/or draining dialysate. Abdominal pain and fever are inconstant. Peritonitis is most often of bacterial origin (sometimes mycotic, viral, or parasitic). Positive diagnosis is confirmed by Sero hematological analysis of the dialysis fluid, which reveals more than 100 leukocytes/mm3, over 50% of which are neutrophils. The most common germs are staphylococci, BGN, and enterococci. Management is hospital-based, with the start of probabilistic intraperitoneal antibiotic therapy with a C3G anti-pyocyanic agent (ceftazidime or aminoside), with or without an anti-staphylococcal glycopeptide (vancomycin or teicoplanin), to be adapted subsequently [34].

## ADEQUACY OF DIALYSIS

PD cannot be limited to uremic toxins. PD must help maintain euvolemia and normal blood pressure. To achieve this, it must ensure adequate UF and sodium balance. Sodium intake must therefore be restricted, and water intake adapted to the patient. Normal phosphatemia values should be achieved, which is facilitated by the use of long dialysis cycles. Residual renal function should be preserved as far as possible [2]. Prescriptions for volumes and contact times should be adjusted by means of peritoneal equilibration tests, if necessary, and the use of icodextrin. Adequacy will also be measured by satisfactory clinical and nutritional status, harmonious growth in height and weight requiring regular monitoring of blood pressure based on Z scores according to the child's height and gender and biological parameters including measurement of Kt/V urea.

## CONCLUSION

Peritoneal dialysis is a simple and effective treatment modality for the management of chronic renal failure in children. It has the advantage of preserving vascular access routes, an essential element in a long-term treatment strategy, as well as enabling home-based management, thus helping to maintain school attendance.

Nevertheless, this method requires considerable daily commitment on the part of parents, which can represent a significant emotional and organizational burden. For this reason, regular, structured support from a pediatric nephrology referral center is essential to ensure treatment safety, support families, and optimize the child's quality of life.

## AUTHORS' CONTRIBUTIONS

Rouba Bechara wrote the article, Bruno Ranchin reviewed and corrected it, Ariane Zaloszyc gave the idea for the article, took part in writing it and corrected it

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## CONFLICTS OF INTEREST

*The authors declare that they have no conflict of interest with this article.*

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