Peripherally inserted central catheters for calcium requirements after successful parathyroidectomy: a comparison with centrally inserted catheters

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ABSTRACT

BACKGROUND Intravenous calcium supplements are often required following parathyroidectomy to avoid postoperative hypocalcaemia. The aim of this study was to compare application effect of a femoral central venous catheter (CVC) and peripherally inserted central catheter (PICC) on intravenous calcium supplements after parathyroidectomy.

METHODS We retrospectively reviewed the hospital records of 73 patients with secondary hyperparathyroidism who underwent a successful parathyroidectomy at the Huashan Hospital attached to Fudan University between 1 April 2011 and 1 February 2016.

RESULTS Of the 73 study participants, 39 (53.4%) had a PICC and 34 (46.6%) had a CVC, respectively. Patients in the CVC group needed 6–7 days of intravenous calcium supplements, while patients in PICC group needed only 2–3 days to achieve normal serum calcium concentration (2.2–2.6 mmol/L). Furthermore, the duration of calcium supplementation was 71.62 ± 4.48 hours in PICC group and 100.4 ± 5.43 hours in CVC group ($P < 0.05$). Of the patients in PICC group, the incidence of catheter occlusion, operation failure and hypocalcaemia was 0%, which was significantly lower than those in CVC group (2.56%, 7.69% and 7.69%, respectively).

CONCLUSIONS PICC is a safe and efficient alternative in contrast to CVC for providing venous access for calcium supplementation in surgical patients after parathyroidectomy.

KEYWORDS

Peripherally inserted central catheter – Calcium requirements – Central venous catheter – Secondary hyperparathyroidism – Parathyroidectomy

Accepted 2 December 2016

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Introduction

Secondary hyperparathyroidism is a common acquired disorder and a frequent complication seen in chronic renal failure. Parathyroidectomy began to be used in 1960 as an alternative treatment to reduce the gland mass.¹ Research shows that parathyroidectomy can improve symptomatology and quality of life in patients with secondary hyperparathyroidism, and has potential clinical value.^{2–4} Hypocalcaemia is one of the common complications following parathyroidectomy.⁵ Hyperparathyroidism occurs in up to 95% of patients with secondary hyperparathyroidism.⁷ Patients are at high risk of hypocalcaemia with symptoms such as tetany, cardiac arrhythmia and even sudden death.^{6,7} Transient postoperative hypocalcaemia, broadly referred to hungry bone syndrome, is often found following parathyroidectomy.⁸ To avoid postoperative hypocalcaemia, intravenous calcium supplements are often required. Upon successful removal of the parathyroid adenoma, an aggressive ‘over-replacement’

of calcium was adopted, immediately infusing high doses of intravenous calcium. Continuous intravenous calcium infusion was maintained and the levels were titrated with the serial serum calcium levels and patient’s symptoms if any.⁹

Recently, intravenous calcium given via a peripheral intravenous infusion has been reported in the literature.^{10,11} However, intravenous calcium should be administered into large veins or via a central line, because the extravasation of calcium solution may cause soft tissue and skin necrosis.¹² The use of a central venous catheter (CVC) for the administration of drugs is common in infusion therapy. Clinicians presume that the CVC serves as a conduit to the central circulation, and provides a reliable method in the hospital setting to rapidly deliver drugs.¹³ Surgeons generally choose the groin (femoral vein) as the CVC in parathyroidectomy, because of the ease of operation. In addition, the position of the insertion does not affect the surgical site. However, a growing body of literature suggests that femoral vein

insertion should be avoided since femoral CVC has a relatively high rate of bacterial colonisation and occlusion.^{14,15}

A peripherally inserted central catheter (PICC) is an alternative method of central venous access and has been shown to be a cost effective way of safely administering chemotherapy.^{16,17} PICC is used for many of the same purposes as CVC and is commonly inserted at the bedside by specially trained nurses.¹⁸ PICCs have been used successfully in cancer patients because of their quicker and easier management.^{19,20} Since then, PICC has usually been inserted into the patient's arm. This route is associated with a lower risk of central line-associated bloodstream infection than CVC,²¹ although earlier studies suggested that a PICC was not advisable in patients with renal failure who might require haemodialysis, owing to the need to preserve essential upper-extremity veins for later fistulas or grafts.²²

With the development of PICC insertion under ultrasound guidance, the traditional blind puncture technique for PICC is gradually being replaced by the ultrasound-guided modified Seldinger technique. This technique has shown significant benefits over the traditional blind puncture method in improving the first-attempt success rate and reducing the incidence of complications.²³ PICC nurses choose the peripheral vein of insertion on the upper part of the elbow joint, commonly the cephalic, basilic or brachial vein.^{24,25} Insertion above the elbow can shorten the length of PICC and can also make the patient more comfortable. Arteriovenous fistula most commonly occurs below the elbow, suggesting no conflict with the PICC insertion site.²⁶

PICCs are quicker and easier to insert through ultrasound-guided technique at the bedside.²⁷ Clinical outcomes have shown that patients have good acceptance of PICC because of the ease of positioning and low rate of complications.²⁸ PICC nurses can rapidly verify placement with ultrasound and reduce the damage to upper-extremity veins as much as possible through a modified Seldinger technique.²⁹ PICCs have many advantages, although there are no relevant studies of PICC applied to intravenous calcium. In the present study, we aimed to apply PICCs in intravenous calcium requirement after parathyroidectomy.

The purpose of this study was to compare the effects of using femoral CVCs and PICCs on intravenous calcium supplements after parathyroidectomy. The primary research questions of the study were: 1) Are there significant differences in time and amount of intravenous calcium necessary after parathyroidectomy between these two types of lines? 2) Do PICCs have any advantages in intravenous calcium compared with femoral CVCs?

Materials and Methods

The hospital records of 73 patients with secondary hyperparathyroidism who underwent a successful parathyroidectomy (postoperative decrease in parathyroid hormone, PTH, level by more than 80%) at the Huashan Hospital attached to Fudan University between 1 April 2011 and 1 February 2016 were reviewed in detail. There were 34 patients in the PICC group and 39 patients in the CVC group. The CVC was placed in the right femoral vein in the CVC group. In the

PICC group, the catheter was placed in the arm without arteriovenous fistula in haemodialysis patients. Patient information included demographics and laboratory data during the period of intravenous calcium consumption after parathyroidectomy. Details concerned the changes in serum calcium, intravenous calcium supplements and duration, catheter operations and patient complication.

Immediately after parathyroidectomy, intravenous calcium substitution was initiated with 5% calcium gluconate infusion at a rate of 30mL/hour. The intravenous elementary calcium requirements were calculated and serum calcium levels were tested every 6 hours. Patients were monitored for clinical and biochemical signs of hypocalcaemia. The calcium infusion rate was adjusted by the level of serum calcium to maintain the serum calcium at 2–3mmol/L. There was no standard titration regimen and the infusion adjustment was up to the judgment of the physicians in attendance. Oral calcium and vitamin D supplements were started as soon as the patients' serum calcium was steady in the normal range.

The laboratory parameters analyzed included serum calcium, phosphorus and PTH. These data were arranged by time of analysis. In addition, all PTH measurements available from the time of surgery until discharge day were extracted from the files. The last available PTH value on the day of discharge was retained to evaluate the success of the parathyroidectomy.

Results are expressed as the mean $\pm$ standard deviations. Statistical analysis was performed using one-way analysis of variance. Intergroup comparisons (post hoc analysis) of the data with equal variances were made by Fisher's least significant difference method. Tamhane's T2 method was used for the data with unequal variances. A *P* value of < 0.05 was considered to be significant.

Results

A total of 73 patients were retrospectively enrolled. Of the study participants, 39 (53.4%) had a PICC and 34 (46.6%) had a CVC, respectively. Patient characteristics are summarised in Table 1. In our cohort, age, body mass index and duration of dialysis were comparable between the two groups. The serum PTH levels significantly decreased after operation (Figure 1). The mean standard deviations (SD) pre- and postoperative serum PTH levels were

Table 1 Comparison of demographic data between patients in the central venous catheter (CVC) and peripherally inserted central catheter (PICC) groups

	CVC (<i>n</i> = 39)	PICC (<i>n</i> = 34)	<i>P</i> value
Age at surgery	50.74 $\pm$ 1.69	49.68 $\pm$ 1.84	0.427
Body mass index	21.76 $\pm$ 0.50	22.45 $\pm$ 0.38	0.239
Female (%)	66.67 (<i>n</i> = 26)	50 (<i>n</i> = 17)	
Duration of dialysis	8.68 $\pm$ 0.47	9.08 $\pm$ 0.87	0.678

1790 ± 93.61 ng/L versus 5.54 ± 1.14 ng/L in the PICC group, and 1998 ± 87.75 ng/L compared with 4.98 ± 1.01 ng/L in the CVC group, respectively.

Changes in serum calcium (a) and phosphorus (b) from preoperative levels to 7 day postoperative levels are shown in Figure 2. The range of normal serum calcium is 2.2–2.6 mmol/L. The majority of patients in CVC group needed 6–7 days of intravenous calcium supplements, while those in the PICC group only required 2–3 days to achieve normal serum calcium concentration (Figure 2a). The curve of serum calcium concentration in the PICC group is also more stable than that of the CVC group. Serum phosphorus levels

declined significantly after surgery. There was no significant difference in the curves for serum phosphorus concentration between both groups.

During the first week after surgery, the average elementary calcium intakes were 11.91 ± 0.70 g in the PICC group compared with 13.19 ± 0.76 g in the CVC group. Although calcium supplementation in the PICC group was 9.7% less than in the CVC group, there was no difference in the consumption of calcium (Fig 3a). However, the duration of calcium supplementation was 71.62 ± 4.48 hours for the PICC group and 100.4 ± 5.43 hours for the CVC group ($P < 0.05$) (Fig 3b). Taken together, Figures 2a and 3b demonstrate that the amount of time of medical treatment in the PICC group was significantly lower than in CVC group.

Another result of this study is that the incidence of catheter occlusion and operation failure rates for patients with CVCs was higher than patients with PICCs; 2.56% of patients ($n = 1$) in the CVC group suffered catheter occlusion and in 7.69% of patients ($n = 3$) there was a failure to insert the catheter at the first attempt. Of the 34 patients in PICC group, the incidence of catheter occlusion and operation failure was 0, which was significantly lower than those in CVC group. The incidence of hypocalcaemia in the PICC group was 0, which was significantly lower than that in CVC group ($n = 5$; 7.69%).

Discussion

It is well recognized that an initial rapid fall after parathyroidectomy will produce a decrease in serum calcium with a

Figure 3 Consumption (a) and duration (b) of calcium supplementation in the central venous catheter (CVC) and peripherally inserted central catheter (PICC) groups

trough on the second day.⁵⁰ When serum calcium falls below 2mmol/L, recalcitrant hypocalcaemia is life threatening.⁵¹ Based on the available evidence, substantial amounts of calcium are required to avoid hypocalcaemia following successful parathyroidectomy.^{6,11} Numerous studies support the view that intravenous calcium supplementation works more quickly than oral administration and all patients after parathyroidectomy should be given intravenous calcium infusion therapy.^{6,7,9,32,33} To avoid of these adverse consequences, calcium is commonly infused through femoral CVCs because of ease of operation for surgeons.

A growing body of literature, however, suggests that femoral vein insertion should be avoided, since femoral CVCs have a relatively high rate of bacterial colonisation and occlusion.^{14,15} Femoral CVCs are inconvenient and uncomfortable for patients. In addition, it is difficult for nurses to clean the skin of the insertion site and to change dressings. With recent advances in catheter development and care, PICCs have been increasingly employed. In fact, PICCs are reported to have many advantages, with less risk of bacterial colonisation and catheter occlusion.^{34,35} These advantages are probably due to the insertion site of PICCs; the number of bacteria is lower on the skin of the upper arms than in the infraclavicular, neck and inguinal regions of the skin.^{14,35} Moreover, adding the modified Seldinger technique to a PICC program increases the successful rate of insertion compared with blind insertion.²⁷ Insertion sites in the upper mid-arm (PICC group) showed an increased ambulation than those in the inguinal fold (CVC group). An added advantage is that PICC insertion can be performed by trained nurses at the bedside to shorten surgery time.

No studies have so far focused on the comparison of PICC and CVC in calcium infusion after parathyroidectomy. This study is the first to assess the efficiency of calcium supplementation between PICC and CVC in patients after parathyroidectomy. Providing venous access through central venous catheters is accepted as standard practice in surgical patients after parathyroidectomy. We have demonstrated that PICCs provide a significant advantage in shortening the duration of medical treatment for patients after

parathyroidectomy. The position of the catheter tip makes the difference. The tips of PICCs are required to be positioned on the right atrium entrance where the venous pressure is higher (c. 5–25mmHg).¹⁸ A high blood flow rate in the upper venous cavity will help the serum calcium to diffuse more efficiently.

In this study, we acknowledged that patients in PICC group accept 9.7% less elementary calcium supplementation than patients in the CVC group, with no difference between the two groups. Of note, Byung et al reported that preoperative alkaline phosphatase, preoperative intact parathyroid hormone and phosphorus at 48 hours may be significant factors in estimating the postoperative calcium requirement after parathyroidectomy.⁵⁶ However, Goldfarbyoung et al pointed out that the only identifiable preoperative risk factor for hungry bone syndrome was young age.⁵⁵ According to the pathophysiological mechanism, post-parathyroidectomy hypocalcaemia is an increased shift of calcium from the circulation to the bone tissues. We speculate that there are complicated factors involved in postoperative calcium requirements and further studies are needed to investigate these factors.

We observed a lower occurrence of overall complications in patients with PICC than with CVC. Hypocalcaemia can lead to tetany and ventricular arrhythmia, especially in cardiovascularly vulnerable patients.⁷ Unstable calcium concentration increased the risk of transient hypocalcaemia. Maintaining a serum calcium level in the normal range is of great importance after parathyroidectomy. The effect of calcium infusion through PICC appears to be more stable. There are still many debates over the comparison between PICCs and CVC in terms of complications.

Another result of this study is the demonstration that the incidence of catheter occlusion and operation failure for patients with CVC is higher than with those with PICC. Although ambulation during femoral catheter cannulation may be allowed, leg extension or bend still carries some risk of dislodging the catheter.⁵⁷ Considering the widespread use of PICCs, it is important to evaluate the efficacy, accuracy and safety for depicting drug blood levels from such equipment. There are several comparative studies of the relationship between the serum concentration of drugs and the access for of intravenous infusion since 1999, including a review of literature.^{58–62} Most of these studies have demonstrated a statistically significant difference for plasma drug concentration between different vein access types. Therefore, we believe that varying the site of venepuncture for central catheters will, at least in part, influence drug concentration. It should be noted that all these studies were confined to children, while our research shows a higher calcium concentration in the PICC group than in the CVC group in adult patients. The outcome of this study was just one step in a deep exploration, but it has a profound impact on further investigation for PICC. Further studies should focus on the investigation of the mechanism of drug flow and distribution. Further research should be undertaken to explain the reasons for the difference in drug concentration between the two groups.

Conclusions

Our data indicate that the preponderance of PICCs appeared to be associated with lower duration of intravenous calcium supplementation, a lower incidence of complications and easier insertion. We have demonstrated that PICC is a safe and efficient alternative to CVC for providing venous access for calcium supplements in surgical patients after parathyroidectomy.

Acknowledgement

This work was supported in part by foundations from the Huashan Hospital North attached to Fudan University (2015107), the Huashan Hospital attached to Fudan University (2013QD40) and Shanghai Municipal Commission of Health and Family planning (201540261). The authors declare no conflicts of interest.

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