NDT Plus (2008) 1 [Suppl 1]: i36–i41
doi: 10.1093/ndtplus/sfm043

NDT PLUS
Nephrology Dialysis Transplantation

Potential future uses of calcimimetics in patients with chronic kidney disease

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Abstract

Cinacalcet has proven effective in the treatment of secondary hyperparathyroidism (SHPT) in dialysis patients, and it may also have benefits in stage 3 and 4 chronic kidney disease (CKD). The efficacy of cinacalcet in the treatment of SHPT was investigated in a study of 54 patients with stage 3 and 4 CKD not receiving dialysis. A significant number of these patients achieved at least a 30% reduction in parathyroid hormone (PTH) from baseline with cinacalcet therapy compared with placebo (56% versus 19%; $P = 0.006$). Another potential use of cinacalcet is in the treatment of persistent hyperparathyroidism (HPT) after kidney transplantation. The pathophysiologic considerations for persistent HPT in patients who have undergone renal transplantation are different from those in stage 3 and 4 CKD. Post-transplant patients with normal graft function often present with hypercalcaemia, low serum phosphorus and persistently elevated levels of PTH. In eight small open-label studies including a total of 83 patients with persistent HPT after successful kidney transplantation, cinacalcet treatment effectively corrected hypercalcaemia and significantly reduced elevated PTH levels. These studies suggest that cinacalcet therapy is an effective therapy in controlling hyperparathyroidism in patients with stage 3 and 4 CKD and in post-transplant patients with persistent hyperparathyroidism.

Keywords: chronic kidney disease; persistent hyperparathyroidism; renal transplant

Introduction

Secondary hyperparathyroidism (SHPT) is often underdiagnosed or insufficiently treated in patients not yet receiving dialysis, when therapy would have greater short- and long-term benefits [1]. Hyperparathyroidism also frequently persists after successful renal transplantation [2,3] and is present in up to 50% of patients 1 year after renal transplant surgery [2,4]. Thus, early diagnosis and management of SHPT in chronic kidney disease (CKD) patients and recognition and treatment of persistent hyperparathyroidism in post-transplant patients is important and might reduce morbidity from cardiovascular and bone disease. The efficacy of the calcimimetic cinacalcet was recently explored in these two distinct patient populations. In this article, the manifestations of hyperparathyroidism in stage 3 and 4 CKD and in kidney transplant patients will be discussed, and data regarding the efficacy of cinacalcet in these two groups of patients will be presented.

Manifestations of stage 3 and 4 CKD

Patients with stage 3 and 4 CKD are more likely to die than to progress to end-stage renal disease [5]. Among patients with stage 3 CKD, 24.3% of patients died within 5 years versus 1.3% who progressed to renal replacement therapy. Among patients with stage 4 CKD, 45.7% died within 5 years, compared with 19.9% who progressed to dialysis or transplantation (Figure 1). SHPT is a well-recognized complication of stage 3 and 4 CKD. Accordingly, the National Kidney Foundation Kidney Disease Outcomes Quality Initiative guidelines recommend treatment of SHPT in stage 3 and 4 CKD patients to reduce disease severity and associated morbidity [6]. The under-recognition and undertreatment of SHPT in these patients [1,7] has serious consequences, including vascular calcifications and bone disease [8,9]. Thus, in the context of SHPT, elevated serum phosphorus has been associated with increased mortality risk and with acute myocardial infarction in CKD patients not receiving dialysis [10].

The hypercalcaemia, hyperphosphataemia and increased calcium–phosphorus product (Ca × P) associated with SHPT contribute to the development of vascular calcifications that are commonly observed in chronic dialysis patients [11,12]. The process of vascular calcification begins early in the progression of CKD and continues as kidney function declines [9,13,14]. The incidence of vascular calcifications among CKD patients not receiving dialysis is 40% [9]; this value increases to 64% in patients who are starting dialysis [13] and to 83% in patients established on dialysis [14]. SHPT also contributes to renal bone disease, which may cause additional morbidity in haemodial-

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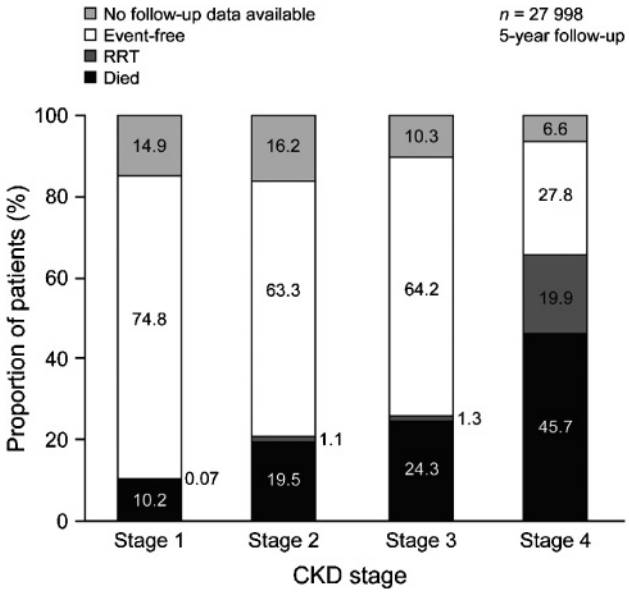

Fig. 1. Prognosis in a population of CKD patients ($n = 27\ 998$). RRT, renal replacement therapy. Adapted with permission from Keith *et al.* [5].

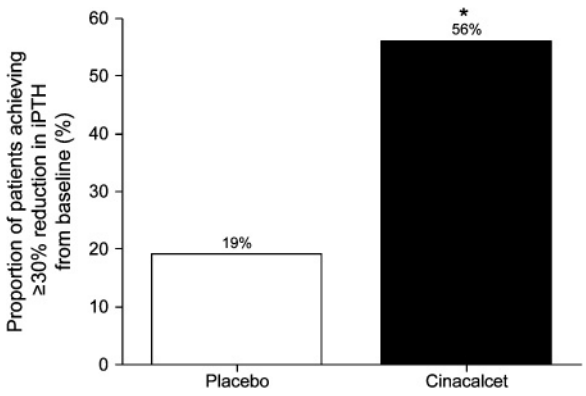

Fig. 2. Percentage of stage 3 and stage 4 CKD patients achieving primary endpoint of ≥30% reduction from baseline in iPTH with cinacalcet ($n = 27$) or placebo ($n = 27$) therapy. $^*P < 0.01$. Adapted with permission from Charytan *et al.* [16].

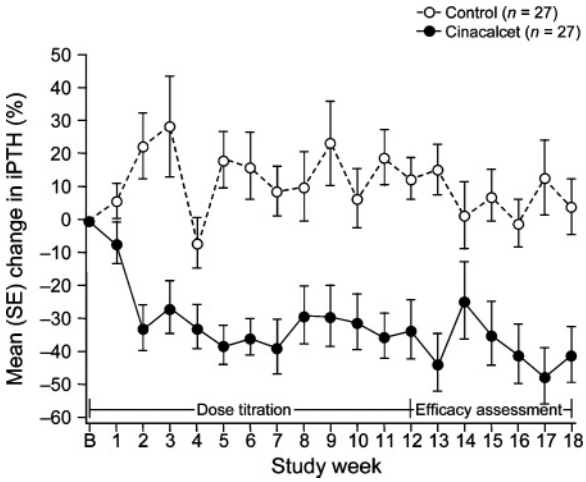

Fig. 3. Reduction of iPTH from baseline (week 0) during treatment with cinacalcet ($n = 27$) or placebo ($n = 27$) in stage 3 and 4 CKD patients. B, baseline; SE, standard error. Adapted with permission from Charytan *et al.* [16]

ysis patients [15]. Once again, the development of renal bone disease occurs early in the progression of CKD. The majority of predialysis patients have mixed osteodystrophy, osteomalacia or adynamic bone disease [8].

Cinacalcet treatment in stage 3 and 4 CKD

Manipulation of the calcium-sensing receptor (CaR) impacts the synthesis and secretion of parathyroid hormone (PTH) and parathyroid gland hyperplasia. Calcimimetics, by modulating the CaR, can directly address the pathophysiology of SHPT early in CKD. Charytan *et al.* [16] reported the results of a double-blind, placebo-controlled trial to determine the safety and efficacy of cinacalcet in 54 patients with stage 3 and 4 CKD. All patients included in the study had a serum intact PTH (iPTH) concentration of >130 pg/mL and a serum calcium concentration of >9.0 mg/dL. Phosphate-binder and/or vitamin D therapy was permitted during the study. Doses of vitamin D could be adjusted appropriately: decreased if hypercalcaemia (calcium >11 mg/dL) or hyperphosphataemia (phosphorus >5.5 mg/dL) occurred, or increased if serum calcium was <8.4 mg/dL or iPTH concentrations were at least 50% greater than baseline on three consecutive visits. The study design consisted of a 12-week titration phase during which the cinacalcet dose was adjusted between 30 and 180 mg/day according to the iPTH and calcium concentrations. Efficacy was assessed during the following 6 weeks of treatment by measuring weekly iPTH concentrations.

More patients treated with cinacalcet achieved the primary endpoint of at least a 30% reduction in iPTH from baseline compared with placebo-treated patients (56% versus 19%, $P = 0.006$; Figure 2). After 2 weeks, mean iPTH decreased by approximately 33% in the cinacalcet group and remained approximately 30% to 40% below baseline for the duration of the study. In contrast, mean iPTH in the placebo group remained near baseline levels throughout the study (Figure 3).

Mean serum calcium concentrations were decreased by 7% in the cinacalcet treatment group but were unchanged (−0.1%) in the placebo group. Patients with CKD not on dialysis receiving cinacalcet were more likely to experience low serum calcium levels compared with those on dialysis [17–20]. In most instances, low serum calcium concentrations (<8.4 mg/dL) were successfully treated by increasing the dose of vitamin D sterols, phosphate binders and/or calcium supplements. Four patients discontinued treatment because of low serum calcium while receiving the lowest dose of cinacalcet, and serum calcium levels returned to normal after stopping therapy. The increased likelihood of hypocalcaemia appeared to be associated with lower calcium concentrations before the commencement of cinacalcet therapy in stage 3 and 4 CKD patients. Urinary calcium excretion was more elevated in the cinacalcet group compared with the placebo group ($P < 0.05$; Table 1) but

Table 1. Effect of cinacalcet on kidney function in patients with stage 3 and 4 CKD

	Placebo ($n = 27$)	Cinacalcet ($n = 27$)
Baseline GFR (mL/min/1.73 m^2) (mean ± SE)	23.1 ± 1.3	22.6 ± 1.4
End-of-assessment GFR (mL/min/1.73 m^2) (mean ± SE)	20.5 ± 1.4	22.1 ± 1.9
Percentage change from baseline during the efficacy assessment phase	−6.6	−7.3*
Baseline urine calcium (mg/24 h) (mean ± SE)	33.7 ± 7.1	34.9 ± 8.3
End-of-study urine calcium (mg/24 h) (mean ± SE)	53.9 ± 13.7	74.0 ± 21.0
Percentage change from baseline during the efficacy assessment phase	20	151†

GFR, glomerular filtration rate; SE, standard error.
*Not significant compared with placebo. †$P < 0.05$ compared with placebo.
Percentage changes from baseline were calculated for the entire efficacy assessment phase.
Data from Charytan *et al.* [16].

Table 2. Most common adverse events in stage 3 and 4 CKD patients treated with placebo or cinacalcet

Adverse event, *n* (%)	Placebo ($n = 26$)	Cinacalcet ($n = 27$)
Nausea	2 (7.7)	9 (33.3)
Myalgia	4 (15.4)	7 (25.9)
Diarrhoea	4 (15.3)	6 (22.2)

Data from Charytan *et al.* [16].

remained below the upper limit of normal (300 mg/24 h) in both treatment groups.

Mean serum phosphorus concentrations were increased in the cinacalcet treatment group but were unchanged in the placebo group ($P < 0.05$, cinacalcet versus placebo). This effect of cinacalcet was most likely due to reduced PTH secretion, resulting in reduced urinary excretion of phosphorus. Consistent with this hypothesis, 24-h urine phosphorus excretion was decreased by 13.3% in the cinacalcet group and was unchanged in the placebo group (−1.5%; $P = 0.19$). In the cinacalcet group, Ca × P increased 6.7% from baseline, whereas in the placebo group, Ca × P increased 3.2% from baseline. Importantly, in both the cinacalcet- and placebo-treated groups, the mean values of serum calcium and phosphorus remained within normal limits at each visit.

The glomerular filtration rate was not significantly changed from baseline in either treatment group (Table 1). In addition, cinacalcet was well tolerated in this population of stage 3 and stage 4 CKD patients. The most common adverse events were nausea, myalgia and diarrhoea (Table 2). These side effects were of mild to moderate severity and of short duration. In summary, the results of this study demonstrate, for the first time, the efficacy and safety of cinacalcet in the treatment of SHPT in stage 3 and 4 CKD patients. These findings need to be confirmed, and in particular the determination of an appropriate dosing strategy for this patient population requires further investigation in a phase 3 clinical trial.

Kidney transplant patients

Hyperparathyroidism frequently persists after successful renal transplantation [2,3]. In a study by Lobo *et al.* [4], iPTH levels were measured over a 0.5- to >4-year period in 52 patients with intact graft function after renal transplantation. One year after transplantation, iPTH remained elevated (≥65 pg/mL) in more than 50% of patients. In a similar study, iPTH values were measured in the month preceding kidney transplant and over a mean 69-month follow-up period after transplant in 62 patients with stable graft function [21]. After >2.5 years following transplantation, only 23% of transplant patients with good renal function had normal iPTH levels, and 27% of patients had iPTH values more than twice the upper normal limit (>130 pg/mL) [21].

Persistent hyperparathyroidism causes hypercalcaemia, which is commonly observed following renal transplantation. In a study of 129 transplant patients, Reinhardt *et al.* [22] found that 52% were hypercalcaemic (>10 mg/dL) 3 months after kidney transplantation, and 15% were still hypercalcaemic at 24 months [22]. Post-transplant hypercalcaemia may pose a significant risk for renal and vascular calcifications following transplantation and a subsequent increased risk of cardiovascular death [relative risk (RR) = 2.6; $P = 0.033$] and overall mortality (RR = 1.8; $P = 0.015$) [23]. In the study by Gwinner *et al.*, calcifications in the kidneys were present in 26% of renal transplant patients, and those patients with calcifications had both elevated iPTH and calcium [24]. Interestingly, even though there was no association between serum phosphorus and vascular calcification, post-transplant phosphorus supplementation occurred more frequently in those with vascular calcification [24]. Persistent hyperparathyroidism is also associated with high bone turnover and may contribute to bone disease following transplantation [25].

Of interest, there is a strong relationship between pretransplant and post-transplant hyperparathyroidism. Pretransplant iPTH level was significantly correlated ($r = 0.58$; $P = 0.0001$) with post-transplant iPTH level in patients with normal transplant function >2.5 years after transplantation [21]. A similar relationship between pre- and post-transplant iPTH levels was reported by Messa *et al.* [26]. Correlations between pretransplant and post-transplant iPTH levels have been shown to persist for up to 4 years after transplantation [2]. These studies suggest that treatment of hyperparathyroidism and hypercalcaemia before transplant surgery might help reduce the severity of hyperparathyroidism after transplantation.

The current treatment strategies for hyperparathyroidism after renal transplantation are limited and have important

Table 3. Baseline demographics in renal transplant patients with persistent hyperparathyroidism

	Serra *et al.* [33,38] ($n = 12$)	Kruse *et al.* [36] ($n = 14$)	Szwarc *et al.* [35] ($n = 9$)	Leca *et al.* [37] ($n = 10$)	Srinivas *et al.* [40] ($n = 11$)	Apostolou *et al.* [39] ($n = 7$)	Apostolou *et al.* [34] ($n = 2$)	El-Amm *et al.* [41] ($n = 18$)
Age (years)								
Mean	NR	NR	52	NR	NR	NR	62	45
Range	49–70	23–65	NR	NR	22–64	38–72	52–71	19–66
Sex (*n*)								
Men	6	7	9	NR	6	4	2	8
Women	6	7	0	NR	5	3	0	10
Dialysis duration before study entry (months)								
Mean	32	NR	NR	65	NR	NR	NR	84
Time from renal transplant to study entry (months)								
Mean	28	NR	59	NR	NR	NR	NR	NR
Range	6–384	7–168	NR	NR	2–60	4–35	10–16	1–276
PTH at study entry (pg/mL)								
Mean	190	NR	171	605	NR	424	NR	627
Range	NR	80–1295	NR	NR	99–723	NR	256–407	NR

NR, not reported.

Table 4. Summary of results from cinacalcet studies in post-transplant patients

Study	Reference	Study duration	Cinacalcet patients (*n*)	PTH	Ca	P	Ca × P	Immuno-suppressants	Graft function (creatinine clearance or serum creatinine)
Serra *et al.*	[33,38]	6 months	12	↓	↓	↑	↔	↔	↔
Kruse *et al.*	[36]	3 months	14	↓ns	↓	↔	↔	↔	↓
Szwarc *et al.*	[35]	6 months	9	↓	↓	↑ns	↔	↔	↔
Leca *et al.*	[37]	6 months	10	↓	↓	↑ns	NR	NR	NR
Srinivas *et al.*	[40]	18 months	11	↓ns	↓	↑	NR	↔	↔
Apostolou *et al.*	[39]	18 months	7	↓	↓	↔	NR	↔	↔
Apostolou *et al.*	[34]	14 months	2	↓ns	↓ns	↑ns	NR	↔	↔
El-Amm *et al.*	[41]	6 months	18	↓	↓	↑	↔	↔	↓
Total *N*			83						

NR, not reported; ns, not significant. Arrows indicate increases, decreases or no change.

side effects. As mentioned above, phosphorus supplementation has been associated with the occurrence of interstitial calcifications in the graft [24]. Vitamin D therapy may worsen hypercalcaemia [27]. Bisphosphonates generally do not reduce PTH levels significantly and may promote low turnover bone disease [28]. Parathyroidectomy is effective to lower PTH and to correct hypercalcaemia; however, several studies have suggested that renal allograft function may deteriorate, and cases of graft loss have been described after parathyroidectomy [29–32]. Based on these data, more suitable and safer therapies that correct persistent hyperparathyroidism and hypercalcaemia and the consequent morbidity would be beneficial to this group of patients.

Cinacalcet treatment in renal transplant patients

Given that hyperparathyroidism remains a problem for many patients after successful renal transplantation [2–4], and because there are few effective therapeutic options [33], there has been interest in novel treatments for the control of hyperparathyroidism in this group of patients. The effect of cinacalcet in patients with persistent hyperparathyroidism after renal transplant has been reported in a number of small prospective and retrospective open-label studies in transplant patients with stable allograft function [34–41]. In general, patients in these studies had stable renal function with mean creatinine clearances in the range of 30–75 mL/min. The primary objective of cinacalcet therapy was control of post-transplant hypercalcaemia, and cinacalcet was titrated to achieve this endpoint. Oral vitamin D therapy was not permitted in the studies by Szwarc *et al.* [35], Serra *et al.* [33,38] and Srinivas *et al.* [40] but was permitted in the study by Kruse *et al.* [36]. Leca *et al.* [37] avoided the use of vitamin D, whereas Apostolou *et al.* [34,39] allowed its use once calcium levels were normalized. The duration of treatment in these studies was up to 18 months. In general, the cinacalcet dosage needed to control hypercalcaemia was relatively low (average, 30–40 mg/day).

Baseline characteristics of the studies are summarized in Table 3. Overall, efficacy results across the studies were consistent (Table 4). Within 2 to 4 weeks of cinacalcet treatment, serum iPTH was significantly reduced and maintained over the treatment duration (10 weeks to 14 months) [34,35,37,38]. In the study by Kruse *et al.* [36], the sustained reduction in iPTH levels after cinacalcet treatment was not significant because of large iPTH differences among patients and the small sample size. Leca *et al.* reported that

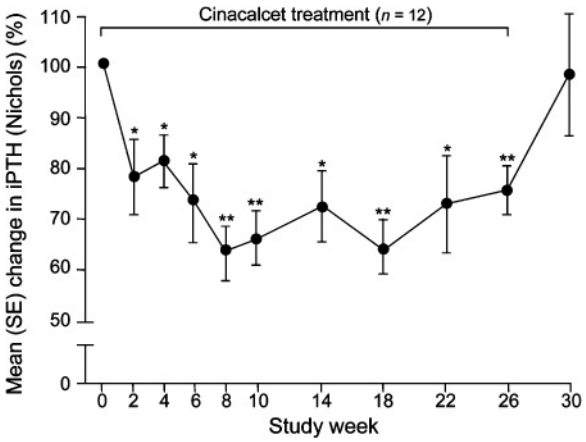

Fig. 4. Reduction in iPTH during treatment with cinacalcet in renal transplant recipients ($n = 12$). $^{*}P < 0.01$, $^{**}P < 0.001$ compared with baseline (week 0). SE, standard error. Adapted with permission from Serra *et al.* [33].

cinacalcet reduced serum iPTH from baseline by an average of 40% during the first month of treatment; iPTH levels remained 40–50% lower than baseline for the duration of the 6-month follow-up [37]. Similarly, Serra *et al.* [33] observed a maximal reduction in iPTH following 8 weeks of cinacalcet treatment, with reduced iPTH being maintained for 26 weeks (Figure 4).

Cinacalcet significantly reduced calcium levels within days of treatment, and calcium levels overall were maintained in the normal range over the treatment periods [33–41]. Serra *et al.* [33] reported that serum calcium was maintained within normal limits in all patients for 6 months, with serum-ionized calcium being reduced by 17.7%. Kruse *et al.* [36] reported normalization of serum calcium in 12 of 14 patients. In the case report by Apostolou *et al.* [34], calcium levels declined rapidly after just 1 day of cinacalcet treatment. In general, serum phosphorus remained unchanged or was increased towards the normal range [34–41]. In one study, after 6 months of treatment with cinacalcet, 90% of patients had serum phosphorus levels within the normal range [33]. When it was measured, serum Ca × P remained unchanged (Table 4) [33,35,36,38,41].

Graft function was measured in seven studies of renal transplant patients treated with cinacalcet, and renal function remained stable in five of the studies (Table 4) [33–36,38–41]. In one study, the glomerular filtration rate, measured by serum creatinine prediction equations, declined over the observation period of cinacalcet treatment; however, the observation period was only 3 months, precluding conclusions regarding long-term graft function [36]. In another study [41], the decline in the glomerular filtration rate after cinacalcet therapy was consistent with the rate of decline before treatment, and therefore, this may not have been a result of cinacalcet therapy. There was no reported interference of cinacalcet with immunosuppressants, and no increase in rejection episodes was reported in these studies. In summary, the results of these small studies show that treatment with cinacalcet effectively normalized hypercalcaemia and significantly reduced iPTH levels in renal transplant recipients, without adversely affecting graft function. Larger studies are required to confirm these findings and to obtain long-term data regarding safety and efficacy.

Summary and conclusions

In patients undergoing chronic dialysis, cinacalcet has been demonstrated to substantially improve the control of SHPT compared with standard care [17–19,42,43]. The role of calcimimetics in the treatment of SHPT in stage 3 and 4 CKD patients and in the treatment of persistent hyperparathyroidism in post-transplant patients is less well characterized. Nonetheless, the CaR is a promising target for these two distinct patient populations.

In the early studies reported here, cinacalcet significantly reduced iPTH concentrations by more than 30% in most patients with stage 3 and 4 CKD. In kidney transplant patients, cinacalcet therapy significantly reduced calcium and iPTH levels and placed phosphorus into the normal range. These early clinical studies suggest that cinacalcet is effective in controlling mineral metabolism in patients with stage 3 and 4 CKD and post-renal transplantation. Because these studies were of short duration and included only small numbers of patients, long-term studies in larger groups of patients are needed to fully evaluate the efficacy and safety of cinacalcet in these populations.

Acknowledgements. The authors wish to thank Carol Berry and Ali Hassan for providing medical writing assistance in the preparation of this manuscript. This supplement and online open access are sponsored by Amgen Inc.

Conflict of interest declaration. Michel Chonchol has participated in advisory boards for Amgen. Rudolf P. Wüthrich has served as an advisor and speaker for Amgen, Astellas, Novartis, Roche and Vifor.

References

1. Kausz AT, Guo H, Pereira BJ *et al*. General medical care among patients with chronic kidney disease: opportunities for improving outcomes. *J Am Soc Nephrol* 2005; 16: 3092–3101
2. Evenepoel P, Claes K, Kuypers D *et al*. Natural history of parathyroid function and calcium metabolism after kidney transplantation: a single-centre study. *Nephrol Dial Transplant* 2004; 19: 1281–1287
3. Cundy T, Kanis JA, Heynen G *et al*. Calcium metabolism and hyperparathyroidism after renal transplantation. *Q J Med* 1983; 52: 67–78
4. Lobo PI, Cortez MS, Stevenson W *et al*. Normocalcemic hyperparathyroidism associated with relatively low 1:25 vitamin D levels post-renal transplant can be successfully treated with oral calcitriol. *Clin Transplant* 1995; 9: 277–281
5. Keith DS, Nichols GA, Gullion CM *et al*. Longitudinal follow-up and outcomes among a population with chronic kidney disease in a large managed care organization. *Arch Intern Med* 2004; 164: 659–663
6. K/DOQI Guidelines 2003. K/DOQI clinical practice guidelines for bone metabolism and disease in chronic kidney disease. *Am J Kidney Dis* 2003; 42: S1–S201
7. De Boer IH, Gorodetskaya I, Young B *et al*. The severity of secondary hyperparathyroidism in chronic renal insufficiency is GFR-dependent, race-dependent and associated with cardiovascular disease. *J Am Soc Nephrol* 2002; 13: 2762–2769

8. Coen G, Ballanti P, Bonucci E *et al*. Renal osteodystrophy in predialysis and hemodialysis patients: comparison of histologic patterns and diagnostic predictivity of intact PTH. *Nephron* 2002; 91: 103–111
9. Russo D, Palmiero G, De Blasio AP *et al*. Coronary artery calcification in patients with CRF not undergoing dialysis. *Am J Kidney Dis* 2004; 44: 1024–1030
10. Kestenbaum B, Sampson JN, Rudser KD *et al*. Serum phosphate levels and mortality risk among people with chronic kidney disease. *J Am Soc Nephrol* 2005; 16: 520–528
11. Block GA. The impact of calcimimetics on mineral metabolism and secondary hyperparathyroidism in end-stage renal disease. *Kidney Int Suppl* 2003: S131–S136
12. Goodman WG, Goldin J, Kuizon BD *et al*. Coronary-artery calcification in young adults with end-stage renal disease who are undergoing dialysis. *N Engl J Med* 2000; 342: 1478–1483
13. Spiegel D, Raggi P, Mehta R *et al*. Coronary and aortic calcifications in patients new to dialysis. *Hemodial Int* 2004; 8: 265–272
14. Chertow GM, Burke SK, Raggi P. Sevelamer attenuates the progression of coronary and aortic calcification in hemodialysis patients. *Kidney Int* 2002; 62: 245–252
15. Horl WH. The clinical consequences of secondary hyperparathyroidism: focus on clinical outcomes. *Nephrol Dial Transplant* 2004; 19(Suppl 5): V2–V8
16. Charytan C, Coburn JW, Chonchol M *et al*. Cinacalcet hydrochloride is an effective treatment for secondary hyperparathyroidism in patients with CKD not receiving dialysis. *Am J Kidney Dis* 2005; 46: 58–67
17. Block GA, Martin KJ, de Francisco AL *et al*. Cinacalcet for secondary hyperparathyroidism in patients receiving hemodialysis. *N Engl J Med* 2004; 350: 1516–1525
18. Lindberg JS, Culleton B, Wong G *et al*. Cinacalcet HCl, an oral calcimimetic agent for the treatment of secondary hyperparathyroidism in hemodialysis and peritoneal dialysis: a randomized, double-blind, multicenter study. *J Am Soc Nephrol* 2005; 16: 800–807
19. Lindberg JS, Moe SM, Goodman WG *et al*. The calcimimetic AMG 073 reduces parathyroid hormone and calcium × phosphorus in secondary hyperparathyroidism. *Kidney Int* 2003; 63: 248–254
20. Moe SM, Cunningham J, Bommer J *et al*. Long-term treatment of secondary hyperparathyroidism with the calcimimetic cinacalcet HCl. *Nephrol Dial Transplant* 2005; 20: 2186–2193
21. Torres A, Rodriguez AP, Concepcion MT *et al*. Parathyroid function in long-term renal transplant patients: importance of pre-transplant PTH concentrations. *Nephrol Dial Transplant* 1998; 13(Suppl 3): 94–97
22. Reinhardt W, Bartelworth H, Jockenhovel F *et al*. Sequential changes of biochemical bone parameters after kidney transplantation. *Nephrol Dial Transplant* 1998; 13: 436–442
23. Hernandez D, Rufino M, Bartolomei S *et al*. Clinical impact of preexisting vascular calcifications on mortality after renal transplantation. *Kidney Int* 2005; 67: 2015–2020
24. Gwinner W, Suppa S, Mengel M *et al*. Early calcification of renal allografts detected by protocol biopsies: causes and clinical implications. *Am J Transplant* 2005; 5: 1934–1941
25. Brandenburg VM, Westenfeld R, Ketteler M. The fate of bone after renal transplantation. *J Nephrol* 2004; 17: 190–204
26. Messa P, Sindici C, Cannella G *et al*. Persistent secondary hyperparathyroidism after renal transplantation. *Kidney Int* 1998; 54: 1704–1713
27. Goodman WG. Recent developments in the management of secondary hyperparathyroidism. *Kidney Int* 2001; 59: 1187–1201
28. Coco M, Glicklich D, Faugere MC *et al*. Prevention of bone loss in renal transplant recipients: a prospective, randomized trial of intravenous pamidronate. *J Am Soc Nephrol* 2003; 14: 2669–2676
29. Lee PP, Schiffmann L, Offermann G *et al*. Effects of parathyroidectomy on renal allograft survival. *Kidney Blood Press Res* 2004; 27: 191–196
30. Garcia A, Mazuecos A, Garcia T *et al*. Effect of parathyroidectomy on renal graft function. *Transplant Proc* 2005; 37: 1459–1461
31. Schwarz A, Rustien G, Merkel S *et al*. Decreased renal transplant function after parathyroidectomy. *Nephrol Dial Transplant* 2007; 22: 584–591.
32. Rostaing L, Moreau-Gaudry X *et al*. Changes in blood pressure and renal function after subtotal parathyroidectomy in renal transplant patients presenting persistent hypercalcemic hyperparathyroidism. *Transplant Proc* 1997; 29: 204–206
33. Serra AL, Savoca R, Huber AR *et al*. Effective control of persistent hyperparathyroidism with cinacalcet in renal allograft recipients. *Nephrol Dial Transplant* 2006; 22: 577–583
34. Apostolou T, Damianou L, Kotsiev V *et al*. Treatment of severe hypercalcemia due to refractory hyperparathyroidism in renal transplant patients with the calcimimetic agent cinacalcet. *Clin Nephrol* 2006; 65: 374–377
35. Szwarc I, Argiles A, Garrigue V *et al*. Cinacalcet chloride is efficient and safe in renal transplant recipients with posttransplant hyperparathyroidism. *Transplantation* 2006; 82: 675–680
36. Kruse AE, Eisenberger U, Frey FJ *et al,* The calcimimetic cinacalcet normalizes serum calcium in renal transplant patients with persistent hyperparathyroidism. *Nephrol Dial Transplant* 2005; 20: 1311–1314
37. Leca N, Lafttavi M, Gundroo A *et al*. Early and severe hyperparathyroidism associated with hypercalcemia after renal transplant treated with cinacalcet. *Am J Transplant* 2006; 6: 2391–2395
38. Serra AL, Schwarz AA, Wick FH *et al*. Successful treatment of hypercalcemia with cinacalcet in renal transplant recipients with persistent hyperparathyroidism. *Nephrol Dial Transplant* 2005; 20: 1315–1319
39. Apostolou T, Kollia K, Damianou L *et al*. Hypercalcemia due to resistant hyperparathyroidism in renal transplant patients treated with the calcimimetic agent cinacalcet. *Transplant Proc* 2006; 38: 3514–3516
40. Srinivas TR, Schold JD, Womer KL *et al*. Improvement in hypercalcemia with cinacalcet after kidney transplantation. *Clin J Am Soc Nephrol* 2006; 1: 323–326
41. El-Amm JM, Doshi MD, Singh A *et al*. Preliminary experience with cinacalcet use in persistent secondary hyperparathyroidism after kidney transplantation. *Transplantation* 2007; 83: 546–549
42. Quarles LD, Sherrard DJ, Adler S *et al*. The calcimimetic AMG 073 as a potential treatment for secondary hyperparathyroidism of end-stage renal disease. *J Am Soc Nephrol* 2003; 14: 575–583
43. Moe SM, Chertow GM, Coburn JW *et al*. Achieving NKF-K/DOQI bone metabolism and disease treatment goals with cinacalcet HCl. *Kidney Int* 2005; 67: 760–771

Received for publication: 17.7.07
Accepted in revised form: 10.9.07