Mineral Bone Disease after Kidney Transplantation

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Plan of the presentation

1. Biochemical abnormalities after kidney transplantation (KT)
2. Bone disease after KT
3. Vascular involvement after KT
4. Treatment

1. Biochemical abnormalities after KT

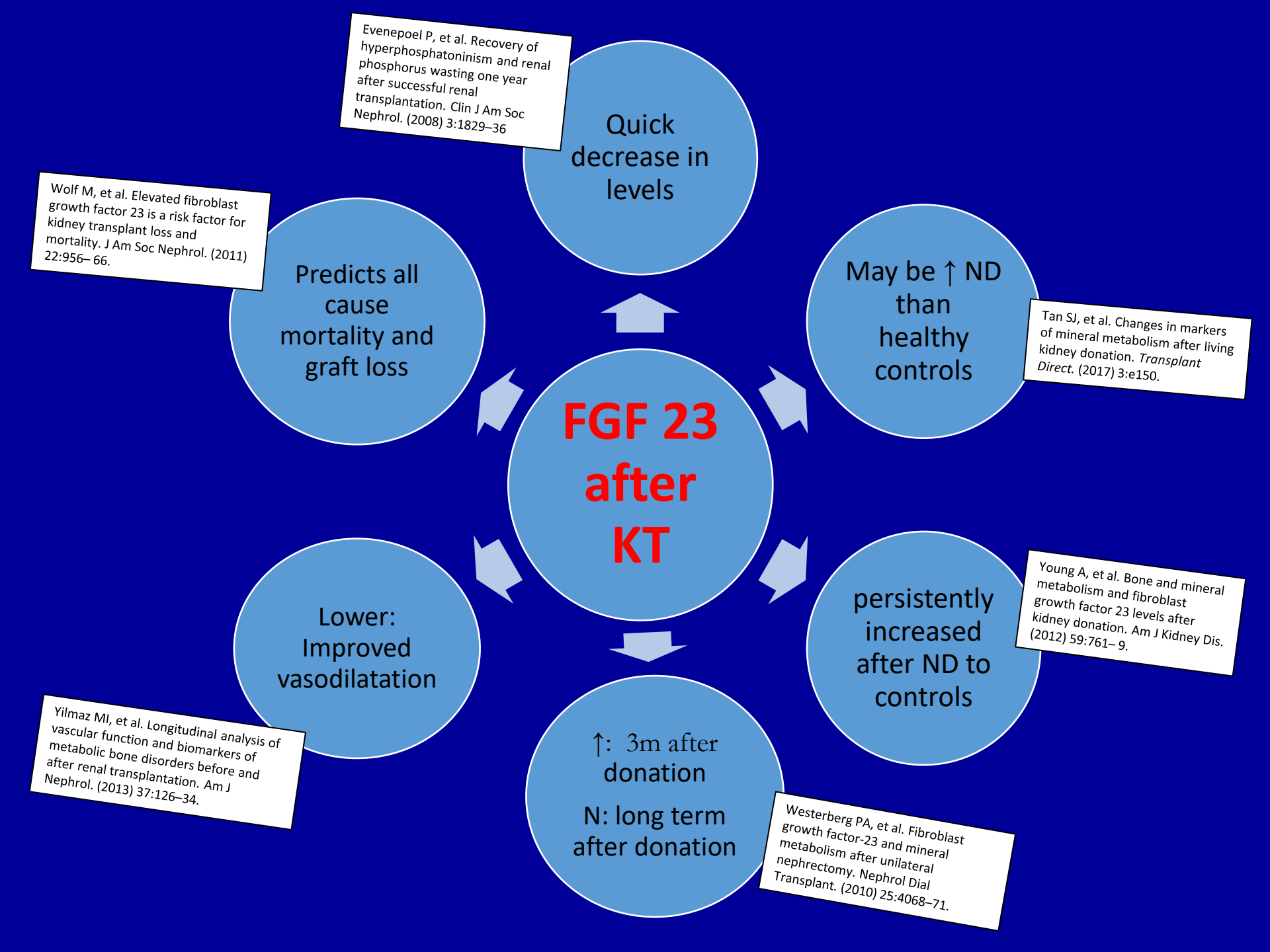
- Depend on the kidney function after KT
- Depend on dialysis duration
- Rapid change over the first 6-12 months post-transplant

After successful KT

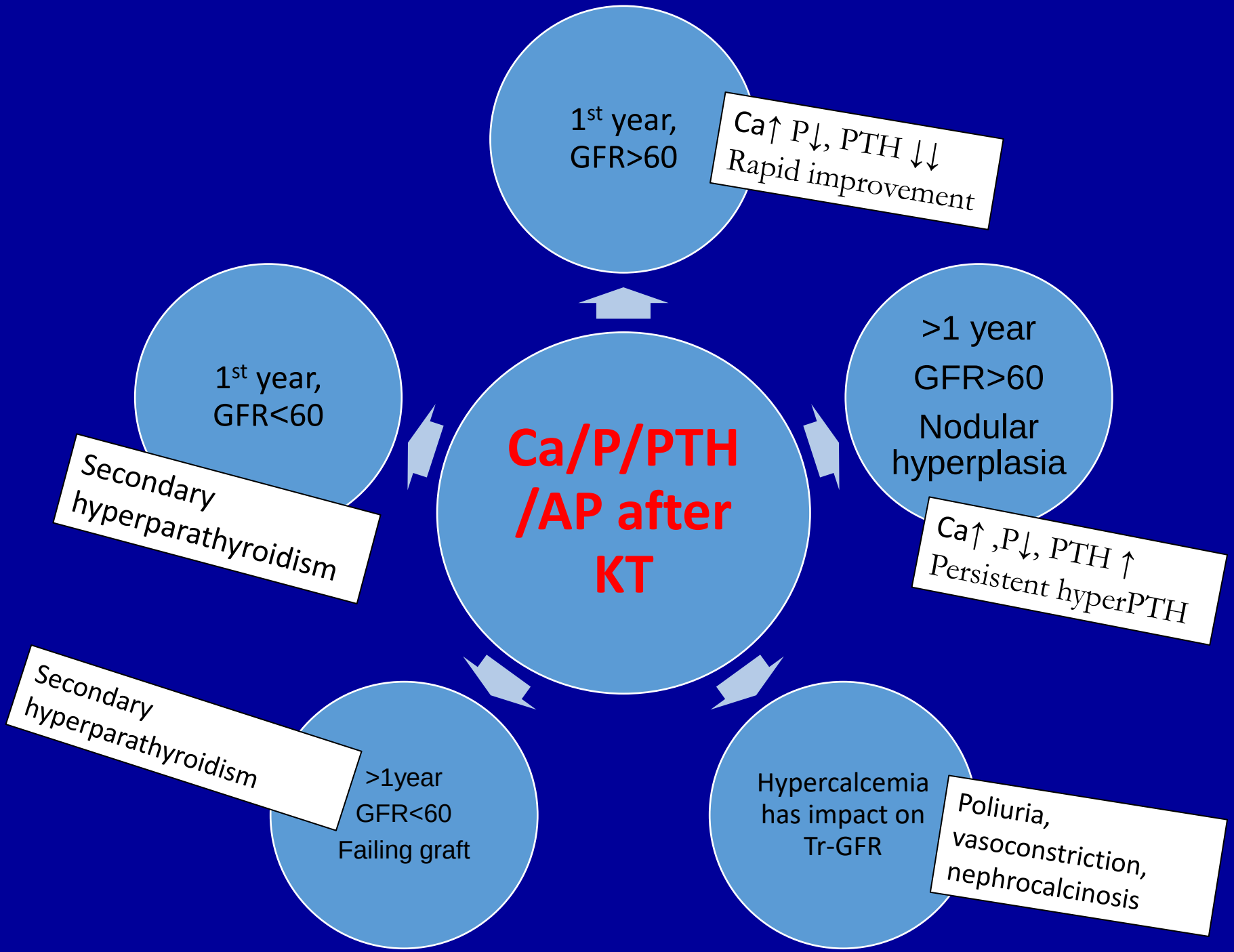
Paramether	Pre-Tx	Post-Tx – 3 mo	Post-Tx – 12 mo
FGF 23	↑↑	↘↘, rapid N	N
sKlotho	↓↓	↗	↓/N
PTH	↑↑	↘	Mostly N
Ca	↓	↗	Mostly N
Phosphate	↑↑	↘↘ hypophosphatemia risk	N
25-OH Vitamin D	↓↓	↓	↓

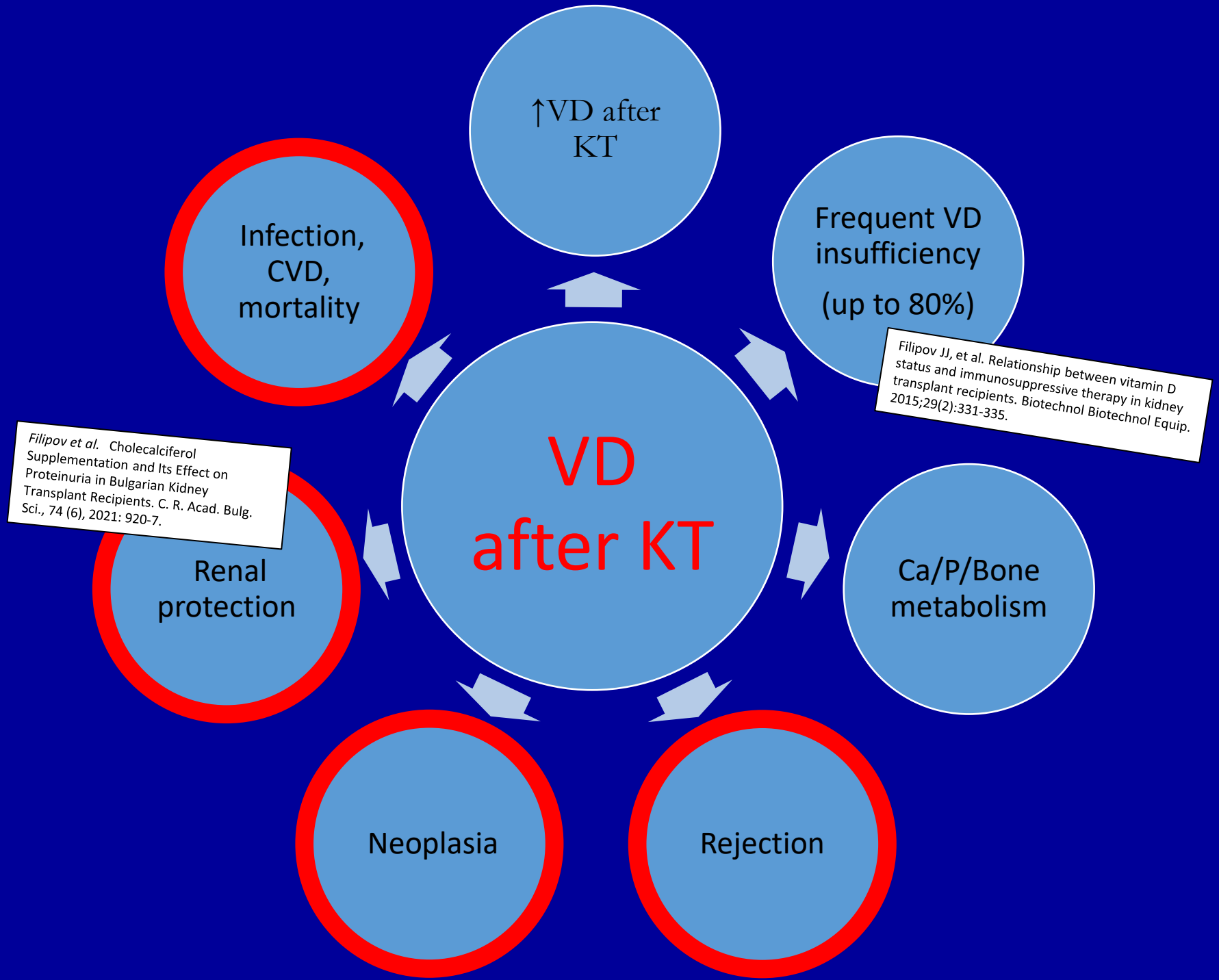
After successful KT

Paramether	Post-Tx	Clinical importance
FGF 23	↘↘, rapid N	Reduced mortality + CVD
sKlotho	↗	Unclear data, better GFR ? No importance ?
PTH, AP	↘	Improved bone health
Ca	↗	Improved bone and vascular health
Phosphate	↘↘ hypophosphatemia risk	Improved bone and vascular health
25-OH Vitamin D	↓	Ca/P and pleiotropy


FGF 23 after KT
Quick decrease in levels
Evenepoel P, et al. Recovery of hyperphosphatoninism and renal phosphorus wasting one year after successful renal transplantation. Clin J Am Soc Nephrol. (2008) 3:1829–36
May be ↑ ND than healthy controls
Tan SJ, et al. Changes in markers of mineral metabolism after living kidney donation. Transplant Direct. (2017) 3:e150.
persistently increased after ND to controls
Young A, et al. Bone and mineral metabolism and fibroblast growth factor 23 levels after kidney donation. Am J Kidney Dis. (2012) 59:761– 9.
↑: 3m after donation
N: long term after donation
Westerberg PA, et al. Fibroblast growth factor-23 and mineral metabolism after unilateral nephrectomy. Nephrol Dial Transplant. (2010) 25:4068–71.
Lower: Improved vasodilatation
Yilmaz MI, et al. Longitudinal analysis of vascular function and biomarkers of metabolic bone disorders before and after renal transplantation. Am J Nephrol. (2013) 37:126–34.
Predicts all cause mortality and graft loss
Wolf M, et al. Elevated fibroblast growth factor 23 is a risk factor for kidney transplant loss and mortality. J Am Soc Nephrol. (2011) 22:956– 66.


sKlotho after KT
↑ after KT
Tan SJ, et al. Mineral adaptations following kidney transplantation. Transpl Int. (2017) 30:463–73.
Lower than healthy subjects
Thongprayoon C, et al. Serum klotho in living kidney donors and kidney transplant recipients: a meta-analysis. J Clin Med. (2020) 9:61834. doi: 10.3390/jcm9061834
Higher on mTORi
Mizusaki K, et al. Inhibition of the mammalian target of rapamycin may augment the increase in soluble Klotho levels in renal transplantation recipients. Blood Purif. (2019) 47(Suppl.2):12–8.
↓ after ND
Ponte B, et al. Acute and long term mineral metabolism adaptation in living kidney donors: a prospective study. Bone. (2014) 62:36–42.
After ND:
↓ than healthy subjects
Tan SJ et al. Changes in markers of mineral metabolism after living kidney donation. Transplant Direct. (2017) 3:e150.

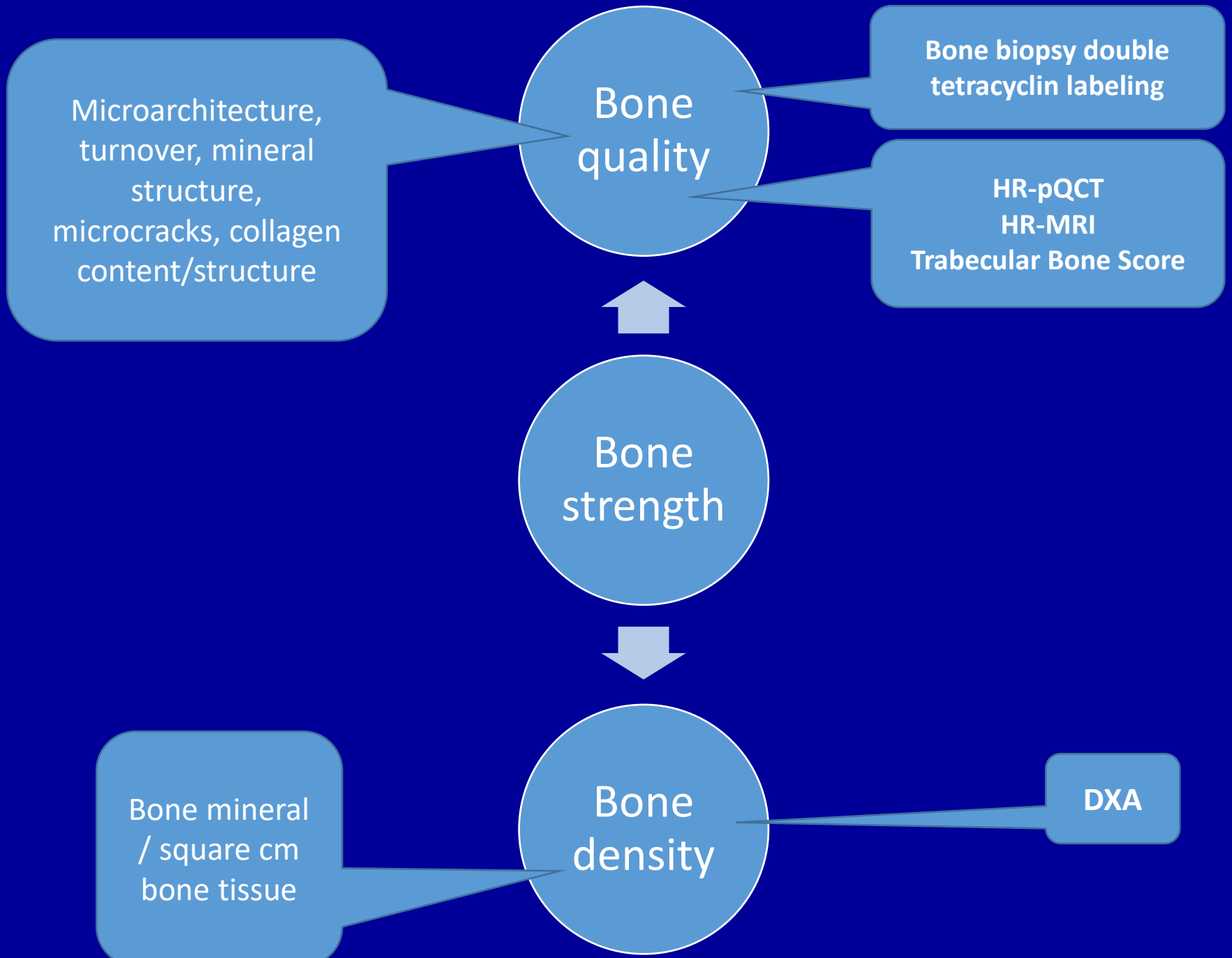

Ca/P/PTH /AP after KT
1st year, GFR>60
Ca↑ P↓, PTH ↓↓
Rapid improvement
>1 year GFR>60 Nodular hyperplasia
Ca↑ ,P↓, PTH ↑
Persistent hyperPTH
Hypercalcemia has impact on Tr-GFR
Poliuria, vasoconstriction, nephrocalcinosis
>1year GFR<60 Failing graft
Secondary hyperparathyroidism
1st year, GFR<60
Secondary hyperparathyroidism


↑VD after KT
Frequent VD insufficiency (up to 80%)
Filipov JJ, et al. Relationship between vitamin D status and immunosuppressive therapy in kidney transplant recipients. Biotechnol Biotechnol Equip. 2015;29(2):331-335.
Ca/P/Bone metabolism
Rejection
Neoplasia
Renal protection
Filipov et al. Cholecalciferol Supplementation and Its Effect on Proteinuria in Bulgarian Kidney Transplant Recipients. C. R. Acad. Bulg. Sci., 74 (6), 2021: 920-7.
Infection, CVD, mortality
VD after KT

2. Post-transplant bone disease

Post-transplant bone disease

- Osteoporosis
- Renal osteodystrophy
- Osteonecrosis
- Bone fracture


Microarchitecture, turnover, mineral structure, microcracks, collagen content/structure
Bone quality
Bone biopsy double tetracyclin labeling
HR-pQCT
HR-MRI
Trabecular Bone Score
Bone strength
Bone mineral / square cm bone tissue
Bone density
DXA

Factors, influencing bone health after KT

Traditional	CKD related	Transplantation-related
Malnutrition	↑ PTH	Steroid use
Age	↓VD	Cumulative steroid dose
Hypogonadism	Systemic inflammation	Persistent ↑PTH
Smoking	Metabolic acidosis	Other IS agents
Lower BMI	Dialysis vintage	Deceased donor
Low physical activity	History of glomerulonephritis	Low GFR
Females		Diabetes
Family history of osteoporosis		Hypomagnesemia
History of fractures		
Diabetes		

Post-KT bone disease: epidemiology & significance

- Major BMD loss – 1 st year post-transplant
- Higher risk for fracture – first 6 months
- Major fracture sites:

  distal (ankle/foot/radius)> hip > spine
- Fractures→ increased mortality (hip + spine)
- Decreasing fracture rates over the last years

Iseri K, et al. Fractures after kidney transplantation: Incidence, predictors, and association with mortality. Bone. 2020;140:115554.

Bouquegneau A, et al. Bone Disease after Kidney Transplantation. Clin J Am Soc Nephrol. 2016 ;11(7):1282-1296.

Bone disease: KT vs dialysis

	Dialysis	Post-transplant
Location	Hip	Distal skeleton
Pathogenesis	CKD, general factors	……+ Post-transplant (IS, rejection, donor)
Total fracture risk	Inconsistent results	Inconsistent results
Hip fracture risk	Higher	Lower
Mortality	Higher	Lower
Bone turnover	↑/↓ (PD/HD)	Further ↓ (CS)
Trabecular volume	N	Steroid-dependent decrease

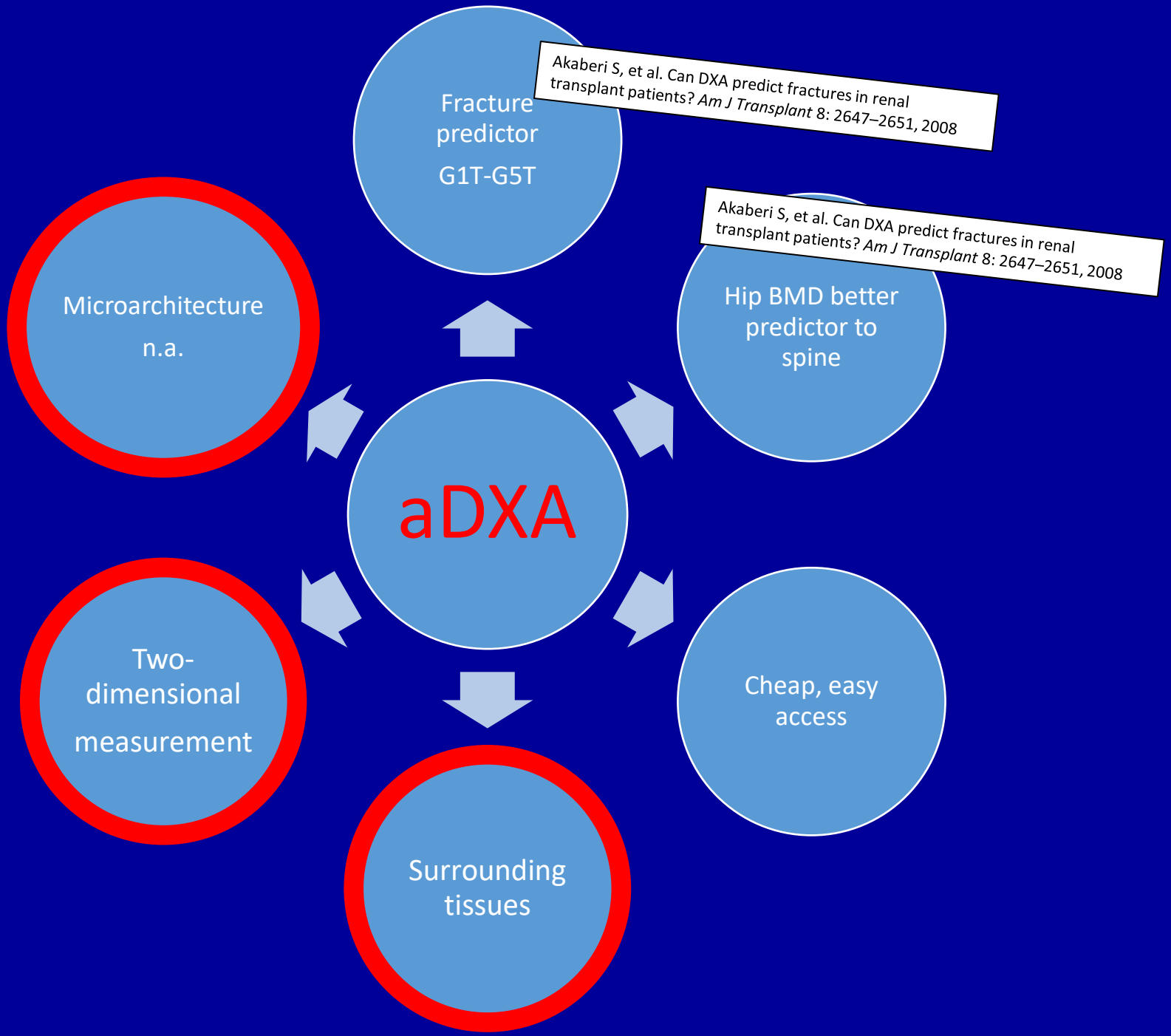
S. Keronen, et al. Changes in bone histomorphometry after kidney transplantation Clin. J. Am. Soc. Nephrol., 14 (6) (2019), pp. 894-903

P. Evenepoel, et al. Bone histomorphometry in de novo renal transplant recipients indicates a further decline in bone resorption 1 year posttransplantation. Kidney Int., 91 (2) (2017), pp. 469-476

Post-transplant bone disease: diagnosis

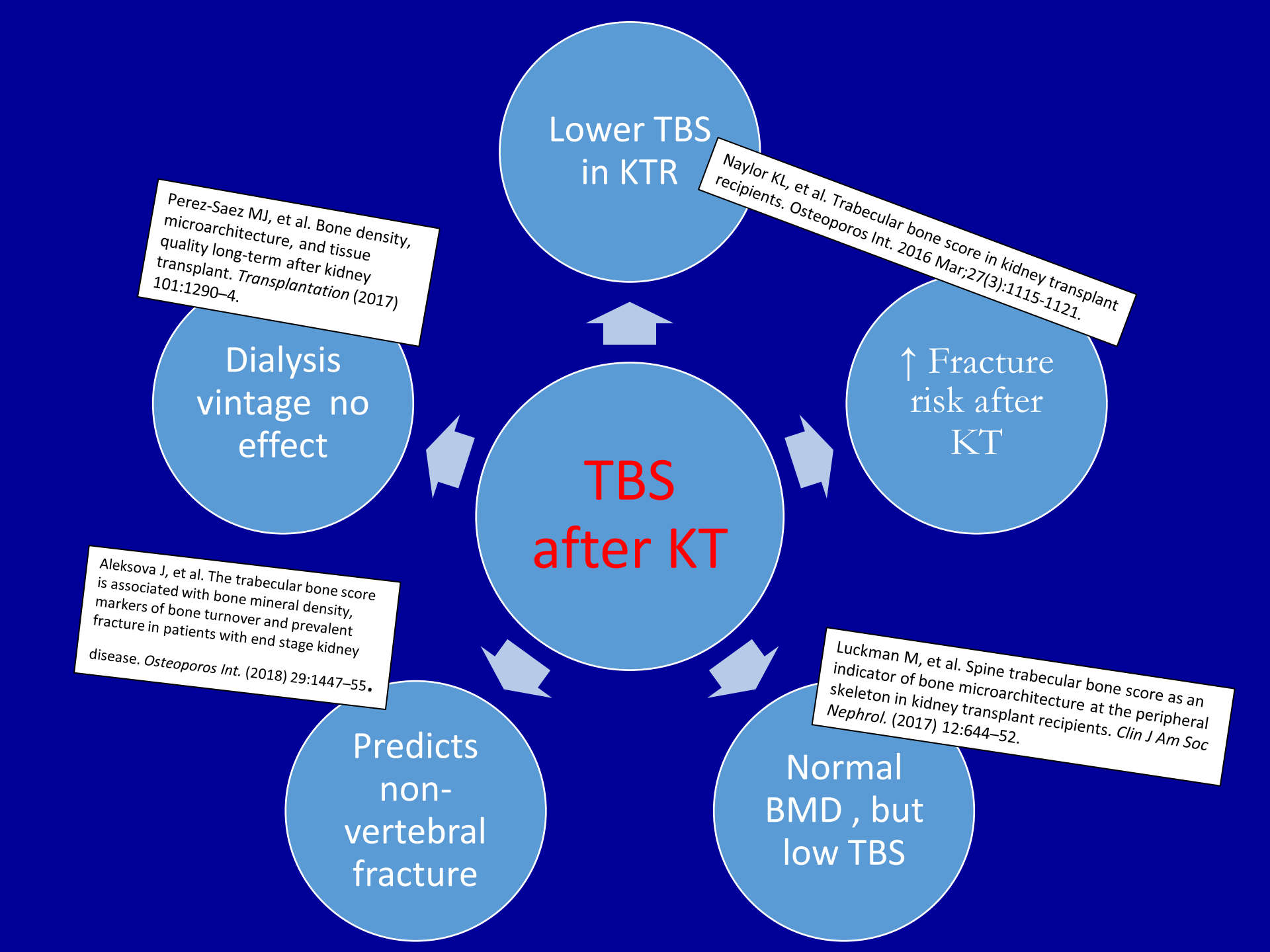
- Imaging techniques : DXA, TBS, HR-pQCT
- Serum markers: bone formation/resorption
- Bone histology

A. Imaging


Fracture predictor
G1T-G5T
Akaberi S, et al. Can DXA predict fractures in renal transplant patients? Am J Transplant 8: 2647–2651, 2008
Hip BMD better predictor to spine
Akaberi S, et al. Can DXA predict fractures in renal transplant patients? Am J Transplant 8: 2647–2651, 2008
Microarchitecture
n.a.
aDXA
Two-dimensional measurement
Cheap, easy access
Surrounding tissues

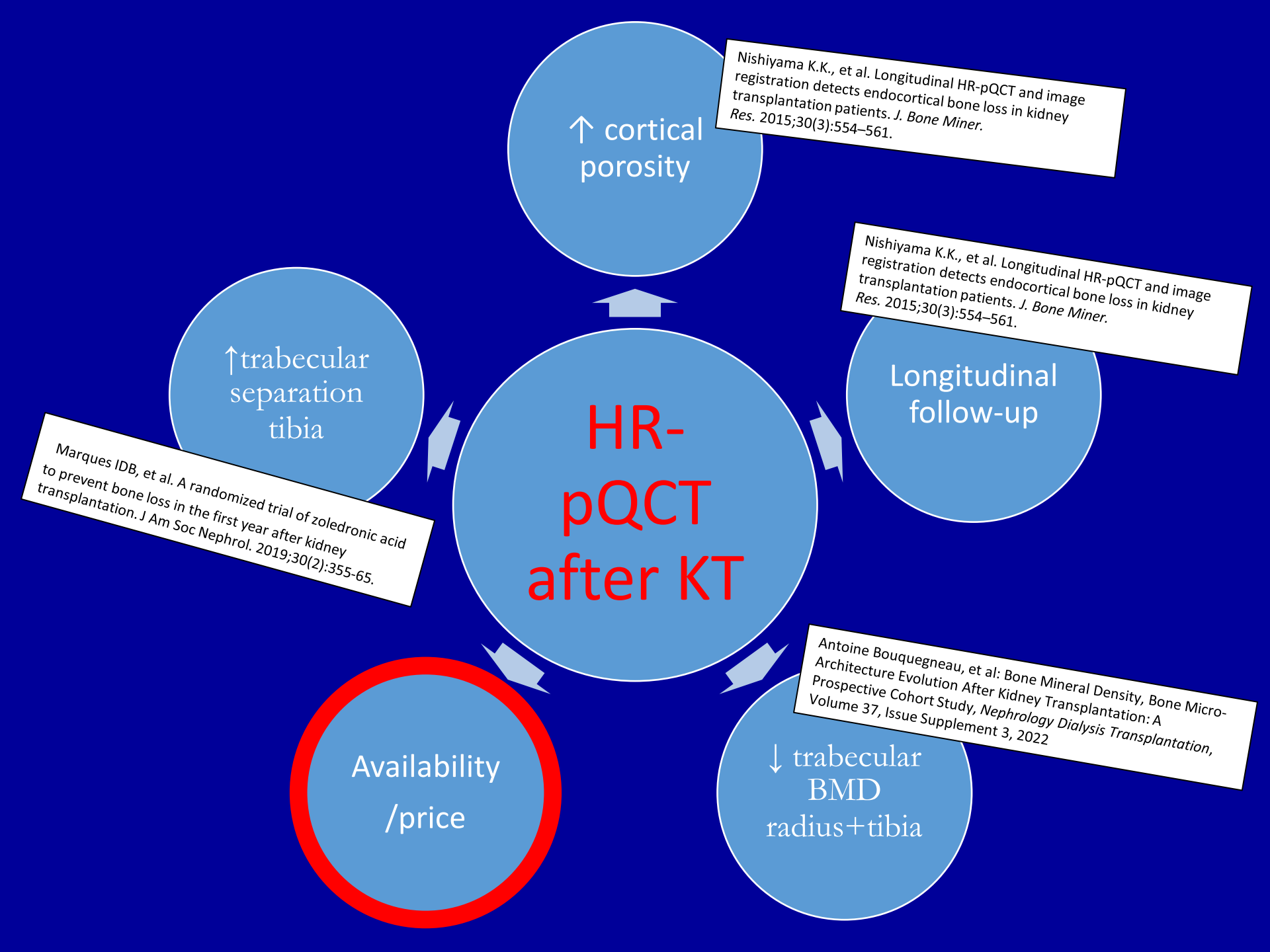
Trabecular bone score (TBS)

- Based on previous lumbar spine – DXA
- Software re-analyzed information
- Evaluates pixel gray-level variations
- Indicates bone microarchitecture
- Evaluates bone strength


TBS after KT
Lower TBS in KTR
Naylor KL, et al. Trabecular bone score in kidney transplant recipients. Osteoporos Int. 2016 Mar;27(3):1115-1121.
↑ Fracture risk after KT
Luckman M, et al. Spine trabecular bone score as an indicator of bone microarchitecture at the peripheral skeleton in kidney transplant recipients. Clin J Am Soc Nephrol. (2017) 12:644–52.
Normal BMD , but low TBS
Predicts non-vertebral fracture
Aleksova J, et al. The trabecular bone score is associated with bone mineral density, markers of bone turnover and prevalent fracture in patients with end stage kidney disease. Osteoporos Int. (2018) 29:1447–55.
Dialysis vintage no effect
Perez-Saez MJ, et al. Bone density, microarchitecture, and tissue quality long-term after kidney transplant. Transplantation (2017) 101:1290–4.

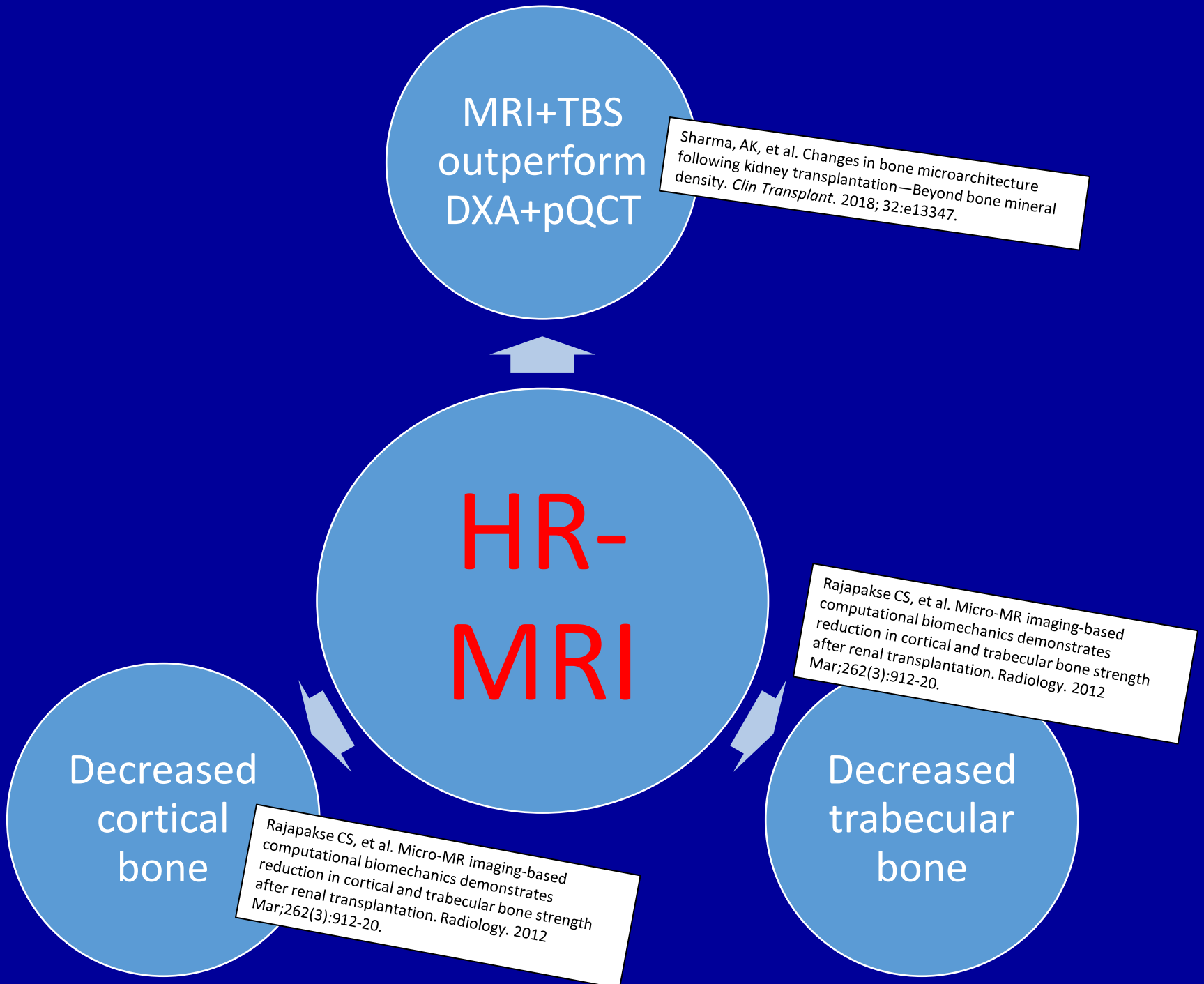
High-resolution peripheral quantitative computed tomography (HR-pQCT)

- CT extremity scanner, imaging up to 3 min
- Obtains 3D bone geometry
- Bone density – overall, compartment – specific
- Microarchitecture evaluation
- Tested regions: distal radius/tibia
- Radiation 3 µSv, DXA – 9 µSv


↑ cortical porosity
Nishiyama K.K., et al. Longitudinal HR-pQCT and image registration detects endocortical bone loss in kidney transplantation patients. J. Bone Miner. Res. 2015;30(3):554–561.
Longitudinal follow-up
Nishiyama K.K., et al. Longitudinal HR-pQCT and image registration detects endocortical bone loss in kidney transplantation patients. J. Bone Miner. Res. 2015;30(3):554–561.
↑trabecular separation tibia
Marques IDB, et al. A randomized trial of zoledronic acid to prevent bone loss in the first year after kidney transplantation. J Am Soc Nephrol. 2019;30(2):355-65.
HR-pQCT after KT
↓ trabecular BMD radius+tibia
Antoine Bouquegneau, et al: Bone Mineral Density, Bone Micro-Architecture Evolution After Kidney Transplantation: A Prospective Cohort Study, Nephrology Dialysis Transplantation, Volume 37, Issue Supplement 3, 2022
Availability /price

High resolution MRI (HR-MRI)

- MRI technique
- Distal extremities
- Proximal femur evaluation also possible
- Similar to HR-pQCT information obtained
- Higher strength of MRI – better clinical correlation


MRI+TBS outperform DXA+pQCT
Sharma, AK, et al. Changes in bone microarchitecture following kidney transplantation—Beyond bone mineral density. Clin Transplant. 2018; 32:e13347.
HR-MRI
Rajapakse CS, et al. Micro-MR imaging-based computational biomechanics demonstrates reduction in cortical and trabecular bone strength after renal transplantation. Radiology. 2012 Mar;262(3):912-20.
Decreased cortical bone
Rajapakse CS, et al. Micro-MR imaging-based computational biomechanics demonstrates reduction in cortical and trabecular bone strength after renal transplantation. Radiology. 2012 Mar;262(3):912-20.
Decreased trabecular bone

B. Serum markers

Bone formation	Bone resorption	Turnover regulators
tALP	Deoxypyridinoline	Receptor activator of NF-κB ligand (RANKL) ↑ resortpion
bALP	Hydroxylysine	Osteoprotegerin ↓osteoclastogenesis
Osteocalcin	Pyridinoline	Dickkopf-1 ↓ formation
Procollagen type 1 N-terminal Propeptide	Bone Sialoprotein	Sclerostin ↓ formation
Procollagen type 1 C-terminal Propeptide	Osteopontin (OP)	
	Cathepsin K	
	Carboxy-terminal Crosslinked Telopeptide of type 1 collagen (CTX-1) (β Crosslaps)	
	Tartrate-resistant acid Phosphatase 5b (TRAP 5b)	
	Amino-terminal Crosslinked Telopeptide of type 1 collagen	
	PTH	

In the general population

Bone formation	Bone resorption	Turnover regulators
tALP	Deoxypyridinoline	Receptor activator of NF-κB ligand (RANKL) ↑ resortpion
bALP	Hydroxylysine	Osteoprotegerin ↓osteoclastogenesis
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	Tartrate-resistant acid Phosphatase 5b (TRAP 5b)	
	Amino-terminal Crosslinked Telopeptide of type 1 collagen	
	PTH	

In the general population + CKD 1-2 ?

Bone formation	Bone resorption	Turnover regulators
tALP	Deoxypyridinoline	Receptor activator of NF-κB ligand (RANKL) ↑ resortpion
bALP	Hydroxylysine	Osteoprotegerin ↓osteoclastogenesis
Osteocalcin	Pyridinoline	Dickkopf-1 ↓ formation
Procollagen type 1 N-terminal Propeptide	Bone Sialoprotein	Sclerostin ↓ formation
Procollagen type 1 C-terminal Propeptide	Osteopontin (OP)	
	Cathepsin K	
	Carboxy-terminal Crosslinked Telopeptide of type 1 collagen (CTX-1) (β Crosslaps)	
	Tartrate-resistant acid Phosphatase 5b (TRAP 5b)	
	Amino-terminal Crosslinked Telopeptide of type 1 collagen	
	PTH	

CKD 3 – 5D

Bone formation	Bone resorption	Turnover regulators
tALP	Deoxypyridinoline	Receptor activator of NF-κB ligand (RANKL) ↑ resortpion
bALP	Hydroxylysine	Osteoprotegerin ↓osteoclastogenesis
Osteocalcin	Pyridinoline	Dickkopf-1 ↓ formation
Procollagen type 1 N-terminal Propeptide	Bone Sialoprotein	Sclerostin ↓ formation
Procollagen type 1 C-terminal Propeptide	Osteopontin (OP)	
	Cathepsin K	
	Carboxy-terminal Crosslinked Telopeptide of type 1 collagen (CTX-1) (β Crosslaps)	
	Tartrate-resistant acid Phosphatase 5b (TRAP 5b)	
	Amino-terminal Crosslinked Telopeptide of type 1 collagen	
	PTH	

CKD biochemistry

After KT

Bone formation	Bone resorption	Turnover regulators
tALP	Deoxypyridinoline	Receptor activator of NF-κB ligand (RANKL) ↑ resortpion
bALP	Hydroxylysine	Osteoprotegerin ↓osteoclastogenesis
Osteocalcin	Pyridinoline	Dickkopf-1 ↓ formation
Procollagen type 1 N-terminal Propeptide	Bone Sialoprotein	Sclerostin ↓ formation
Procollagen type 1 C-terminal Propeptide	Osteopontin (OP)	
	Cathepsin K	
	Carboxy-terminal Crosslinked Telopeptide of type 1 collagen (CTX-1) (β Crosslaps)	
	Tartrate-resistant acid Phosphatase 5b (TRAP 5b)	
	Amino-terminal Crosslinked Telopeptide of type 1 collagen	
	PTH	

CKD biochemistry

Heimgartner N, et al. Predictive Power of Bone Turnover Biomarkers to Estimate Bone Mineral Density after Kidney Transplantation with or without Denosumab: A post hoc Analysis of the POSTOP Study. Kidney Blood Press Res. 2020;45(5):758-767.

Evenepoel P, et al. Bone mineral density, bone turnover markers, and incident fractures in de novo kidney transplant recipients. Kidney Int. 2019 Jun;95(6):1461-1470.

CKD 3T – 5T

Bone formation	Bone resorption	Turnover regulators
tALP	Deoxypyridinoline	Receptor activator of NF-κB ligand (RANKL) ↑ resortpion
bALP	Hydroxylysine	Osteoprotegerin ↓osteoclastogenesis
Osteocalcin	Pyridinoline	Dickkopf-1 ↓ formation
Procollagen type 1 N-terminal Propeptide	Bone Sialoprotein	Sclerostin ↓ formation
Procollagen type 1 C-terminal Propeptide	Osteopontin (OP)	
	Cathepsin K	
	Carboxy-terminal Crosslinked Telopeptide of type 1 collagen (CTX-1) (β Crosslaps)	
	Tartrate-resistant acid Phosphatase 5b (TRAP 5b)	
	Amino-terminal Crosslinked Telopeptide of type 1 collagen	
	PTH	

CKD biochemistry

C. Bone histology

Bone biopsy – importance, indications

- Golden standard, renal osteodystrohpy types, guide for treatment

- In patients with CKD G3a–G5D, it is reasonable to perform a bone biopsy if knowledge of the type of renal osteodystrophy will impact treatment decisions (Not Graded)
- In CKD G3a–G5D + biochemical abnormalities of CKD-MBD and low BMD ± fragility fractures, we suggest that treatment choices take into account the magnitude and reversibility of the biochemical abnormalities and the progression of CKD, with consideration of a bone biopsy (2D)

- KT<12 months, GFR>30 ml/min/1,73m2, low BMD: It is reasonable to consider a bone biopsy to guide treatment (Not graded)

- Inconsistent PTH trend, unexplained calcemia/fractures

Bone histology

- **Turnover:** skeletal remodelling, bone formation/resorption

1. double-tetracycline labeling.
2. low – normal - high

- **Mineralization**: bone collagen calcification

1. Static evaluation – osteoid volume/thickness
2. Dynamic – double tetracycline labelling
3. normal - abnormal

- **Volume**: amount of bone / unit volume tisssue

1. Measured in cancellous bone
2. low – normal - high

TMV classification

Type of ROD	T	M	V
Osteitis fibrosa	High	Normal	High
Adynamic bone disease	Low	Normal	Low/normal
Mild SHT-bone disease	Medium	Normal	Medium
Osteomalacia	Low	Abnormal	Low/medium
MUO osteopathy	High	Abnormal	normal
Normal histology	Normal	Normal	Normal

+ Signs of osteoporosis

thinned trabeculae

decreased osteon size

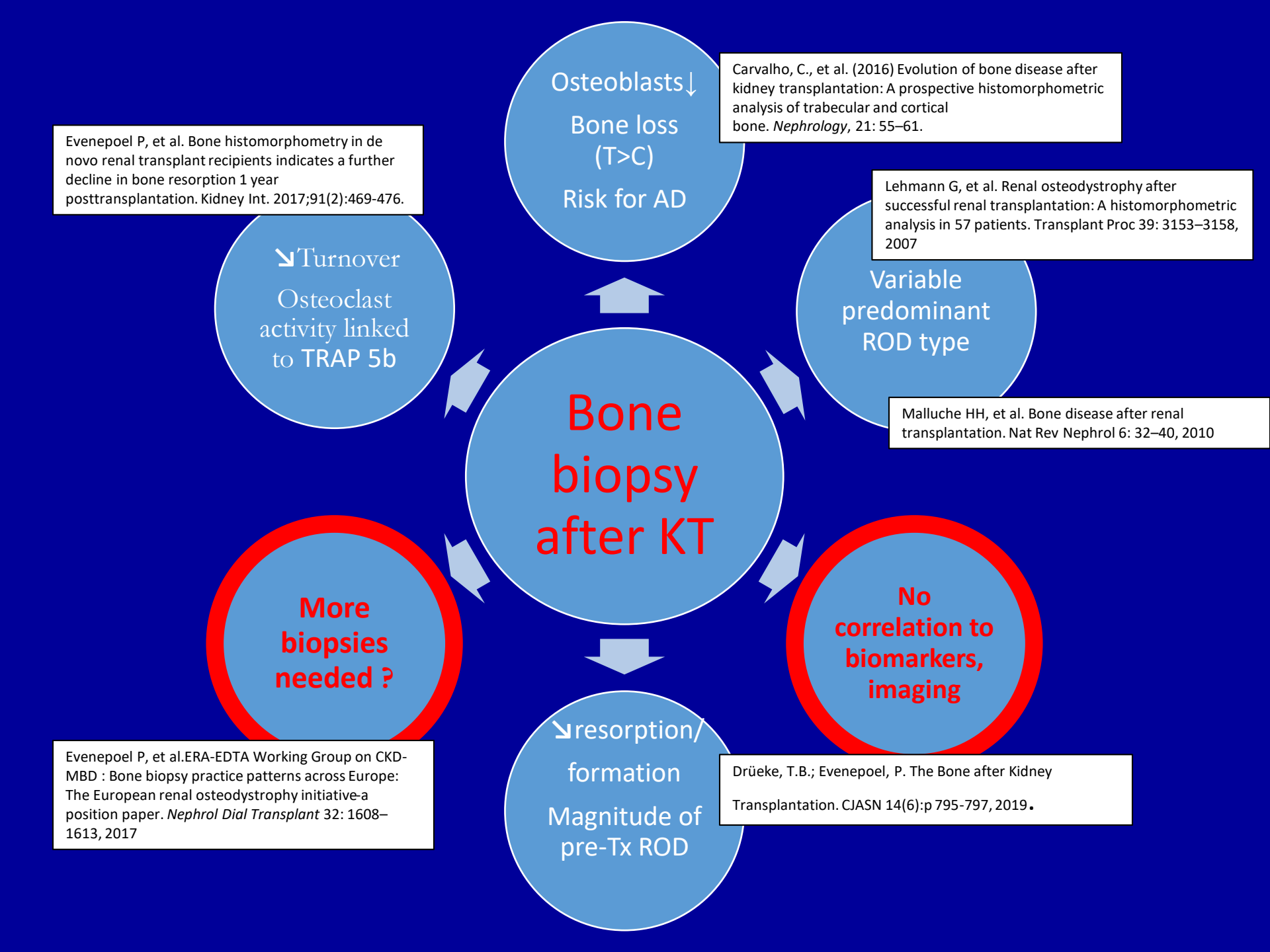
enlarged Haversian and marrow spaces

Moe S, Drüeke T, Cunningham J, Goodman W, Martin K, Olgaard K, Ott S, Sprague S, Lameire N, Eknoyan G; Kidney Disease: Improving Global Outcomes (KDIGO). Definition, evaluation, and classification of renal osteodystrophy: a position statement from Kidney Disease: Improving Global Outcomes (KDIGO). Kidney Int. 2006 Jun;69(11):1945-53.

Bone biopsy: disadvantages

- Expensive
- Invasive
- Pain
- Need for experienced pathologists and laboratory
- Need for experienced operators
- Adequate sampling

- **Still not routinely used, low number of procedures**


Bone biopsy after KT
Osteoblasts↓
Bone loss (T>C)
Risk for AD
Carvalho, C., et al. (2016) Evolution of bone disease after kidney transplantation: A prospective histomorphometric analysis of trabecular and cortical bone. *Nephrology*, 21: 55–61.
Evenepoel P, et al. Bone histomorphometry in de novo renal transplant recipients indicates a further decline in bone resorption 1 year posttransplantation. Kidney Int. 2017;91(2):469-476.
↘Turnover
Osteoclast activity linked to TRAP 5b
Lehmann G, et al. Renal osteodystrophy after successful renal transplantation: A histomorphometric analysis in 57 patients. Transplant Proc 39: 3153–3158, 2007
Variable predominant ROD type
Malluche HH, et al. Bone disease after renal transplantation. Nat Rev Nephrol 6: 32–40, 2010
More biopsies needed ?
Evenepoel P, et al.ERA-EDTA Working Group on CKD-MBD : Bone biopsy practice patterns across Europe: The European renal osteodystrophy initiative-a position paper. *Nephrol Dial Transplant* 32: 1608–1613, 2017
No correlation to biomarkers, imaging
Drüeke, T.B.; Evenepoel, P. The Bone after Kidney Transplantation. CJASN 14(6):p 795-797, 2019.
↘resorption/ formation
Magnitude of pre-Tx ROD

Predictors for bone fracture after KT

Paramether	Fracture risk
Time after KT: first 6 months	↑
Gender: Female	↑
Older recipient, deceased donor	↑
Pre-transplant dialysis	↑
Previous fracture	↑
Treatment acute rejection	↑
Diabetic nephropathy	↑
Preemptive TR	↓
BMD: osteopenia and osteoporosis	↑
FRAX score	Needs further evaluation
Bone markers	Need further evaluation
Bone biopsy	Inconsistent results after KT, need for further evaluation: biopsy result – fracture risk

3. Vascular calcification after KT

Importance

- Associated with higher CV mortality after KT
- Location arterial + valvular calcification
- Relatively common – up to 25%
- Influenced by preceding CKD
- Progression may be slowed down after KT

Risk factors

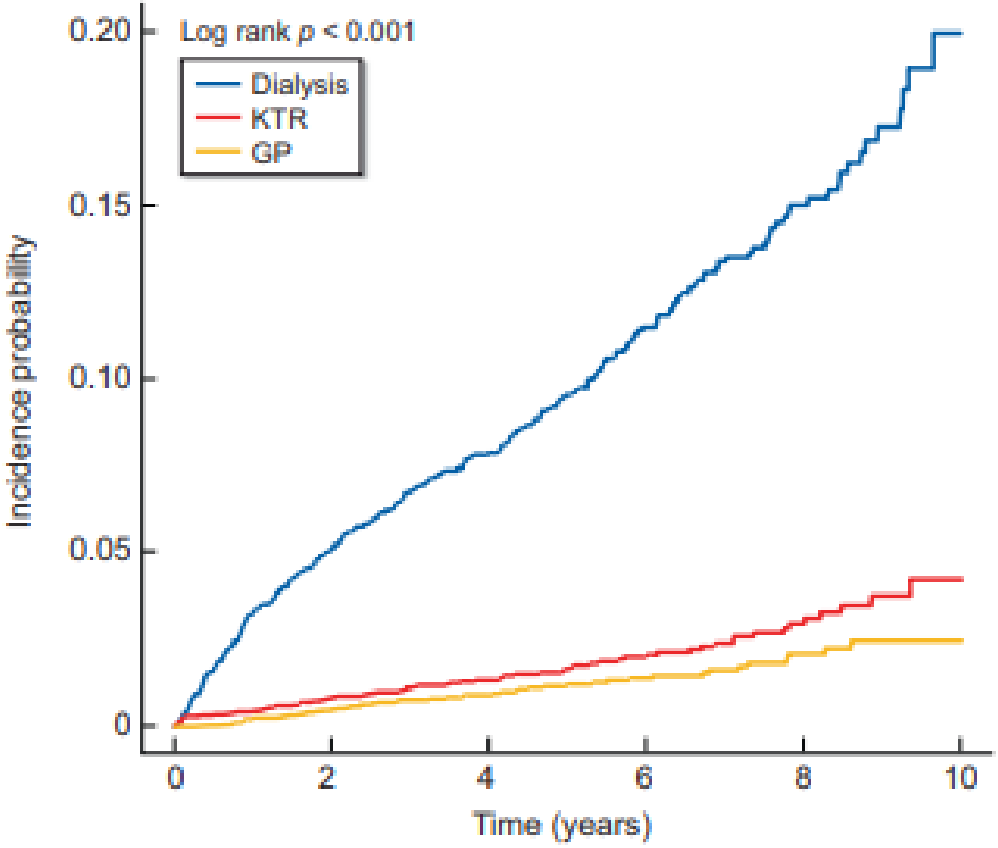
General	Transplant	CKD	Calcification inhibition
Diabetes	Steroids	sHPTH	↓Matrix Gla protein (Vit. K antagonists)
Dyslipidemia	mTOR inhibitors	Systemic inflammation	Hypomagnesemia
Hypertension	CNIs	Oxidative stress	Low Fetulin A
Older age			

Podestà MA, et al. Cardiovascular calcifications in kidney transplant recipients. Nephrol Dial Transplant. 2022;37(11):2063-2071.

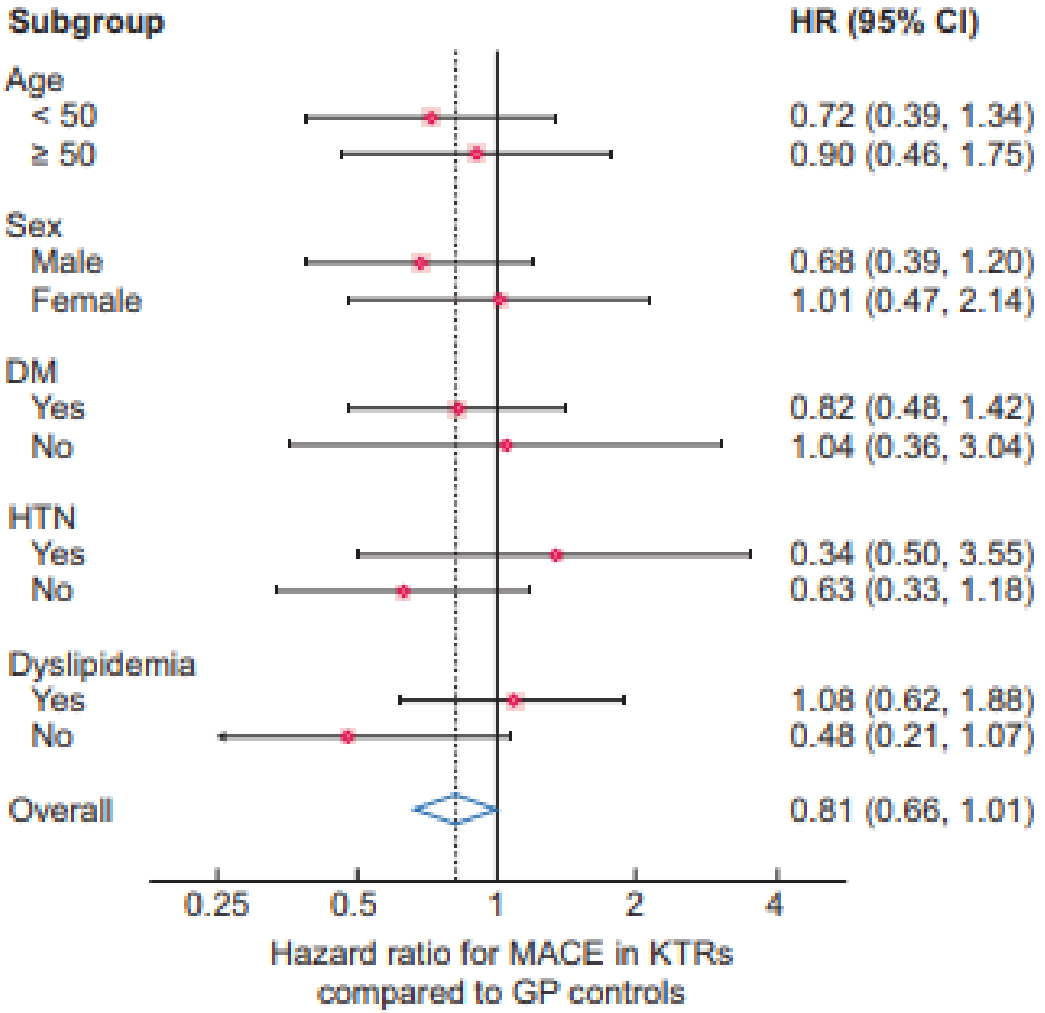
Diagnosis

- CT scan
- Lateral X ray: abdominal, pelvic
- Echocardiography
- DXA scan

CV incidence and mortality after KT

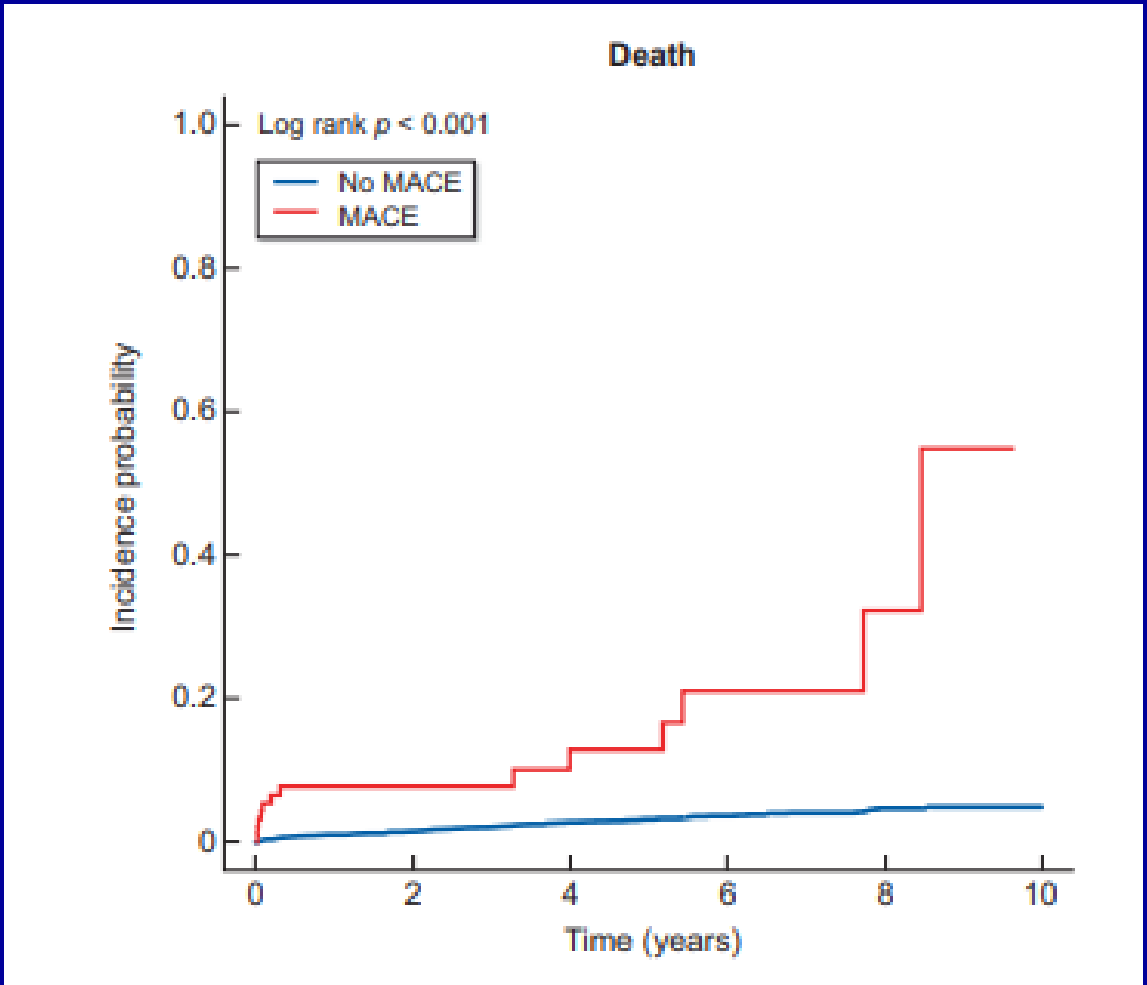


Kim JE, et al. De novo major cardiovascular events in kidney transplant recipients: a comparative matched cohort study. Nephrol Dial Transplant. 2023;38(2):499-506.



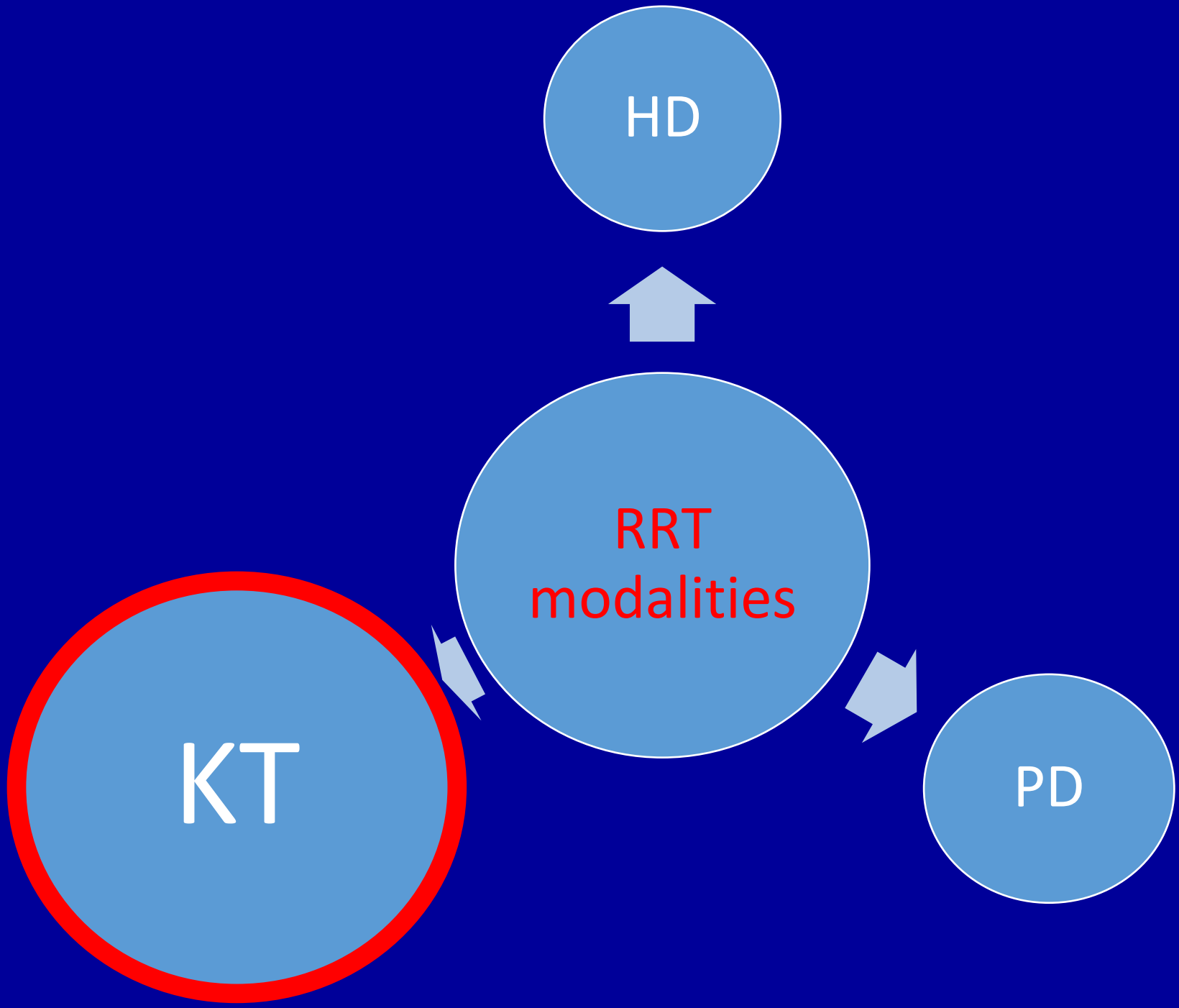
Kim JE, et al. De novo major cardiovascular events in kidney transplant recipients: a comparative matched cohort study. Nephrol Dial Transplant. 2023;38(2):499-506.

MACE and mortality after KT



Kim JE, et al. De novo major cardiovascular events in kidney transplant recipients: a comparative matched cohort study. Nephrol Dial Transplant. 2023;38(2):499-506.

Post-KT mineral bone disease: treatment


HD
RRT
modalities
KT
PD

Post-KT mineral bone disease: treatment and prevention

Biochemistry	Bone	CV involvement
Treatment sHPTH	Steroid minimization	BP control
Ca/P correction	Vitamin D/vitamin D analogue	Dyslipidemia
VD supplementation	Cinecalcet	Treatment sHPTH
Parathyroidectomy	Antiresoptive therapy	Diabetes control
	Recombinant PTH (teriparatide)	Immunosuppression optimization
	Lifestyle modifications	Lifestyle modification

Antiresorptive therapy after KT

- Bisphosphonates + Denozumab
- Lower bone turnover
- Can theoretically worsen pre-existing ABD
- Results – inconsistent
- Bone biopsy can be considered, but not obligatory
- Can be used in patients with high fracture risk

Bisphosphonates and risk of ABD

Author	Bisphosphonate	BMD	Biopsy
Coco et al	*Pamidronate* vs *Calcitriol+Ca*	Slower decline of vertebral BMD in pamidronate	Increased risk of ABD
Haas et al	*Zoledronate + Ca* vs *Ca*	Improvement of lumbar BMD vs controls	No risk of ABD
Coco et al	*Risedronate+Calitriol* vs *Calcitriol*	No change in lumbar BMD	↑osteoid formation, No risk of ABD
Marques et al	*Zoledronate* vs *controls*	Improvement in BMD in both groups	Reduced trabecular bone loss in zoledronate No risk of ABD

Coco M, et al. Prevention of bone loss in renal transplant recipients: A prospective, randomized trial of intravenouspamidronate. J Am Soc Nephrol 14: 2669–2676, 2003

Haas M, et al. Zoledronic acid to prevent bone loss in the first 6 months after renal transplantation. Kidney Int 63: 1130–1136, 2003

Coco M, et al. Effect of risedronate on bone in renal transplant recipients. J Am Soc Nephrol 23: 1426–1437, 2012

Marques IDB, et al. A randomized trial of zoledronic acid to prevent bone loss in the first year after kidney transplantation. J Am Soc Nephrol 30: 355–365, 2019

Denosumab after kidney transplantation

- Humanized monoclonal antibody
- Inhibits the receptor activator of the Nf-kB ligand
- Risk for hypocalcemia, urinary tract infections
- No immunological risk
- Limited trials after KT

Denosumab after kidney transplantation

Author	Design	BMD	Bone biopsy
Alfieri et al.	Denosumab , no control arm	Increased BMD femur and spine	n.a.
Bonani et al.	Denosumab vs controls	Increased femoral and lumber BMD	n.a.
McKee et al.	Denosumab vs bisphosphonates retrospective	Better BMD increase on Denosumab	n.a.
Afifi et al	Denosumab vs Ibandronate	Better BMD on Denosumab	n.a.
Sayed et al.	Denosumab vs Alendronate vs controls	Improvement in BMD on therapy, Denosumab ≈ Alendronate	n.a.

Alfieri C, et al. Bone Effect and Safety of One-Year Denosumab Therapy in a Cohort of Renal Transplanted Patients: An Observational Monocentric Study. J Clin Med. 2021;10(9):1989.

Bonani M, et al. Effect of twice-yearly denosumab on prevention of bone mineral density loss in de novo kidney transplant recipients: a randomized controlled trial. *Am J Transplant.* (2016) 16:1882–91.

McKee H, et al. Correction to: Comparison of the clinical effectiveness and safety between the use of denosumab vs bisphosphonates in renal transplant patients. Osteoporos Int. 2020;31(5):981.

Afifi, M.K., *et al.* Optimization of osteoporosis and osteopenia management among renal transplant recipients. *Futur J Pharm Sci* **7**, 230 (2021).

Sayed, SA, et al. Evaluation of the efficacy and tolerability of alendronate versus denosumab in kidney transplant patients with reduced bone mineral density. *Pharmacotherapy*. 2023; 43: 904-912.

Mineral Bone Disease after Kidney Transplantation: conclusions

- High prevalence
- Numerous risk factors
- Higher mortality
- Poorer quality of life
- Serum biomarkers not very informative
- More bone biopsies needed?
- Modifiable factors present
- More data on treatment expected

Thank you for your attention !