



Bilateral humeral fracture due to vitamin D deficiency: case report

Fractura humeral bilateral por deficiencia de vitamina D: reporte de un caso *Fratura umeral bilateral por deficiência de vitamina D: relato de um caso*

Marcos Antonio Amezcua-Gutiérrez^{1,2*}, Nikolett Iren Medveczky-Ordóñez², Jessica Garduño-López¹, Karen Harumi López-Rodríguez¹, José Carlos Gasca-Aldama¹, Marcos Vidals-Sánchez¹, Ricardo Rodríguez-Villanueva¹, Daniel Antonio Guevara-Cruz².

Received: August 15th, 2023. Accepted: January 29th, 2024.

Published online: February 7th, 2024.

<https://doi.org/10.35454/rncm.v7n1.568>

Summary

Introduction: vitamin D is a fat-soluble vitamin used by the body for bone development and maintenance through the increased absorption of calcium, magnesium, and phosphate. Vitamin D deficiency, or insufficiency, has been identified as a global problem that affects at least one billion people worldwide. The presence of muscle weakness, falls, and fractures associated with vitamin D deficiency is frequent in the elderly; however, its impact on young people is little known.

Clinical case: we present the case of a 34-year-old male with no sun exposure and a history of consuming alcoholic beverages, presenting with progressive muscle weakness and a non-traumatic bilateral humeral fracture associated with vitamin D deficiency. We also describe the diagnostic-therapeutic approach as well as review the literature and its current importance.

Conclusions: vitamin D deficiency is common and often unrecognized, yet it can play an important role in exacerbating underlying pathologies, especially in vulnerable populations. Proximal humerus fractures are common among elderly patients, but not in young people, and less in the absence of trauma. In low-energy fractures without obvious traumatic mechanisms, greater prevalence has been observed in patients with low vitamin levels.

Resumen

Introducción: la vitamina D es una vitamina liposoluble utilizada por el cuerpo para el desarrollo y mantenimiento de los huesos al aumentar la absorción de calcio, magnesio y fosfato. La deficiencia o insuficiencia de vitamina D ha sido identificada como un problema global, ya que afecta al menos a un billón de personas en todo el mundo. La presencia de debilidad muscular, caídas y fracturas asociadas al déficit de vitamina D es frecuente en los ancianos, sin embargo, se conoce poco su impacto en población joven.

Caso clínico: presentamos el caso de paciente masculino de 34 años de edad, sin exposición solar y con antecedentes de consumo de bebidas alcohólicas, que presenta debilidad muscular progresiva y fractura de húmero bilateral no traumática asociada a déficit de vitamina D. También describimos el abordaje diagnóstico-terapéutico realizado, así como una revisión de la literatura y su importancia actual.

Conclusiones: la deficiencia de vitamina D es común y a menudo infradiagnosticada, pero puede desempeñar un papel importante en la exacerbación de patologías subyacentes, especialmente en poblaciones vulnerables. Las fracturas de húmero proximal son frecuentes en pacientes de edad avanzada, pero no en jóvenes, y menos en ausencia de traumatismos. En fracturas de baja energía, sin mecanismo traumático evidente, se ha

Resumo

Introdução: A vitamina D é uma vitamina lipossolúvel utilizada pelo organismo para o desenvolvimento e manutenção dos ossos por aumentar a absorção de cálcio, magnésio e fosfato. A deficiência ou insuficiência de vitamina D foi identificada como um problema global, afetando pelo menos um bilhão de pessoas em todo o mundo. A presença de fraqueza muscular, quedas e fraturas associadas à deficiência de vitamina D é frequente em idosos, entretanto, pouco se sabe sobre seu impacto na população jovem.

Caso clínico: Apresentamos o caso de um doente do sexo masculino, 34 anos, sem exposição solar e com antecedentes de consumo de álcool, que apresentou fraqueza muscular progressiva e fratura bilateral não traumática do úmero associada a deficiência de vitamina D. Descrevemos também o abordagem diagnóstico-terapêutica realizada, bem como uma revisão da literatura e sua importância atual.

Conclusões: A deficiência de vitamina D é comum e muitas vezes subdiagnosticada, mas pode desempenhar um papel importante na exacerbção de patologias subjacentes, especialmente em populações vulneráveis. Fraturas do úmero proximal são comuns em pacientes idosos, mas não em jovens, e menos na ausência de trauma. Nas fraturas de baixa energia, sem mecanismo traumático evi-



Keywords: vitamin D deficiency; humeral fracture; cholecalciferol; bone density.

observado mayor prevalencia en pacientes con niveles bajos de vitaminas.

dente, observa-se maior prevalência em pacientes com baixos níveis de vitaminas.

Palabras clave: deficiencia de vitamina D; fracturas del húmero; colecalciferol; densidad ósea.

Palavras-chave: deficiência de vitamina D; fraturas do úmero; colecalciferol; densidade óssea.

¹ Intensive Care Unit. Hospital Juárez de México. Mexico City, Mexico.

² Intensive Care Unit. Hospital Star Médica. State of Mexico, Mexico.

*Correspondence: Marcos Antonio Amezcua Gutiérrez. amezcua_20@hotmail.com

STATEMENT OF CLINICAL RELEVANCE

Vitamin D plays an important role in calcium homeostasis and bone metabolism, and it influences the immune system, muscle, heart, and nervous system. Muscle weakness, falls, and fractures associated with vitamin D deficiency are frequent in the elderly, but their impact on young people is little known. For this reason, presenting information on the diagnostic-therapeutic approach and reviewing this case is important for knowledge, given its global impact and underdiagnosis.

INTRODUCTION

Vitamin D is not a classic vitamin but a steroid hormone precursor. The vitamin D receptor is expressed in many body tissues, muscle, heart, bone, immune system, skin, and endocrine organs⁽¹⁾. Vitamin D deficiency, or insufficiency, has been identified as a global problem that affects at least one billion people worldwide. More than 40.00 % of U.S. and European elderly men and women are deficient in vitamin D, while in South America the overall prevalence of vitamin D deficiency is 34.76 %^(2,3). Vitamin D is primarily synthesized in the skin through a sunlight-dependent reaction that converts 7-dehydrocholesterol into cholecalciferol. In the liver, it is converted to 25 hydroxyvitamin D [25(OH)D] thanks to the enzyme 25 vitamin D hydroxylase and, finally, in the kidney, to 1,25-dihydroxyvitamin D [1,25(OH)2D]⁽⁴⁾, the active form of the vitamin (**Figure 1**).

The presence of muscle weakness, falls, and fractures associated with vitamin D deficiency is frequent in the elderly. However, its impact on young people is little known, so we present the case of a young patient with a non-traumatic bilateral humeral fracture with vitamin D deficiency as well as a review of the literature and its current importance.

CASE REPORT

We present the case of a 34-year-old male patient who worked in an office, without sun exposure and had a history of alcoholic beverage consumption (>8 g of alcohol/day for three days a week). No significant pathologic history. His condition began with progressive muscle weakness and general malaise exacerbated by a generalized tonic-clonic convulsive episode, with loss of alertness (time not specified) and gaze supraversion, without sphincter relaxation or direct trauma, with a postictal period characterized by somnolence. On admission to the emergency department, alertness was documented, without focalization or lateralization, with decreased muscle strength in the upper extremities and dark-colored urine. His laboratory tests are shown in **Table 1**.

Given the clinical picture and laboratory findings, a simple cranial computed tomography (CT) scan was performed with no evidence of structural alterations, and an abdominal ultrasound showed increased hepatic echogenicity, suggestive of fatty infiltration, without intrahepatic or extrahepatic biliary tract dilatation. Based on the clinical and biochemical findings, the patient was admitted to the intensive care unit (ICU), and treatment for acute kidney injury due to rhabdomyolysis was started with optimization of blood volume and hydroelectrolyte control. During his stay in the ICU, he continued to have neurological integrity without hemodynamic or respiratory deterioration and with adequate urinary flows. However, he presented intense pain in the shoulder that limited mobility and did not improve despite analgesic escalation, so a thoracic CT scan was performed (**Figure 2**), which showed a bilateral metaphyseal distal multifragmentary fracture of the humerus with a non-displaced fracture of the right coracoid process and a fracture of the anterosuperior aspect of the right glenoid labrum. A surgical

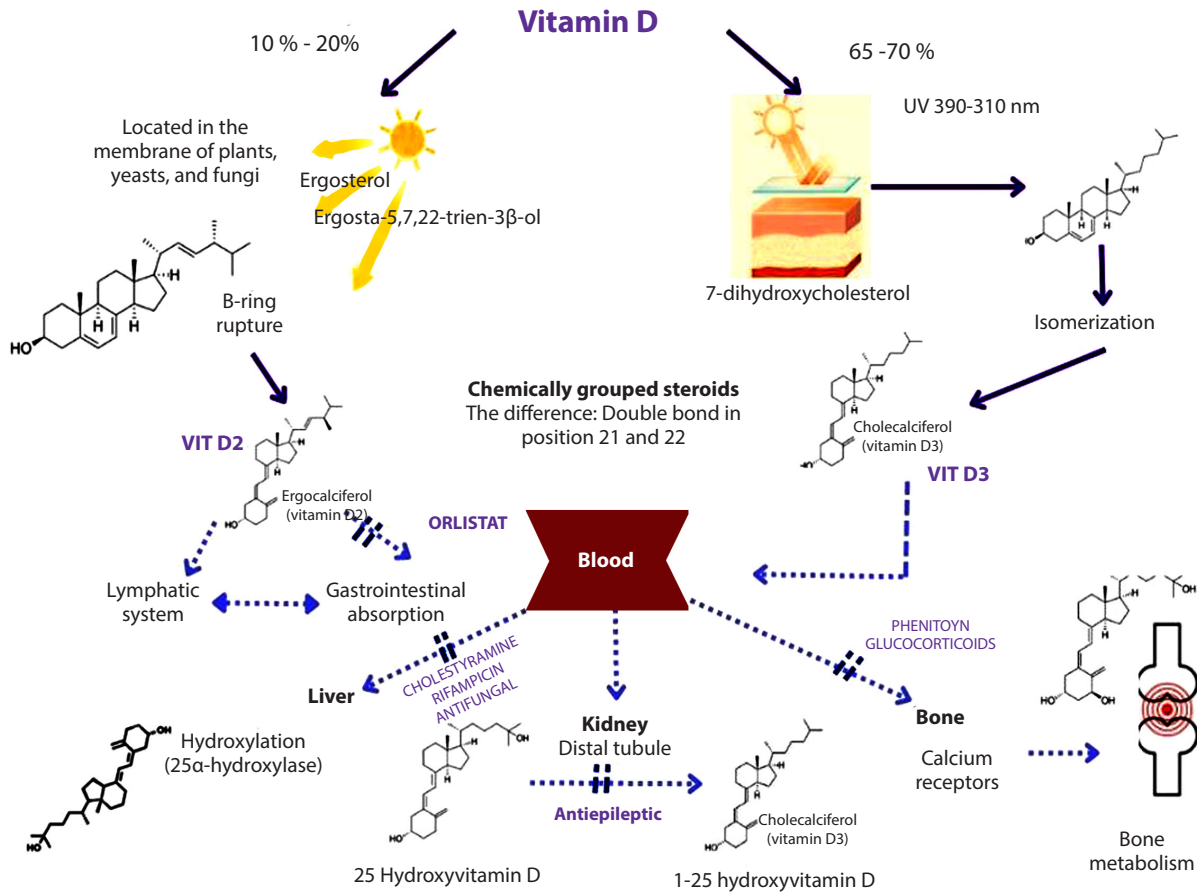


Figure 1. The metabolism of vitamin D has two main sources (animal or vegetable origin), which have ergosterol as a vitamin D precursor, which is converted into ergocalciferol (Vit D2), responsible for 10 % to 20 % of metabolism. The other 70 % to 80 % is obtained from the metabolism of 7-hydroxycholesterol after isomerization by UV rays from sunlight, obtaining cholecalciferol (Vit D3). In the liver, they undergo hydroxylation by 25 a-hydroxylase; in the kidney, it is metabolized in the renal tubule and in the bone matrix by bone metabolism. Some drugs act by inhibiting key points in the metabolism of vitamin D, from absorption to binding to its receptors.

procedure of open reduction and internal fixation with a plate with locking screws was performed.

As part of the patient’s diagnostic protocol and since he did not present direct trauma during the seizure, serum vitamin D 25(OH)D levels of 8 ng/mL (reference range of 30-100 ng/mL) and parathyroid hormone levels of 36.8 pg/mL are documented. Based on the recommendations of the Endocrinology Society, supplementation with vitamin D, 8000 IU per day, was started during hospitalization.

Given the history of frequent alcohol consumption and the biochemical findings: neutrophilia, hyperbilirubin, elevated liver enzymes, AST/ALT ratio >1.5, BT >3 mg/dL, and prolonged coagulation times, he was considered at risk of alcoholic liver disease, according to the criteria of the 2018 European Association

for the Study of the Liver (EASL), and initiated conservative management and close monitoring of liver function.

The patient evolved satisfactorily with correction of renal and hematological function, was asymptomatic, was discharged in good condition after ten days of hospitalization, and subsequently continued with vitamin D at 800 IU per day for three months with serum vitamin D measurements of 28.1 ng/mL. So, it was decided to continue with vitamin D supplementation, physical rehabilitation, and lifestyle changes.

DISCUSSION

The clinical case that we present here shows the relevance that vitamin D has for the organism since it plays

Table 1. Laboratory results. A patient with a bilateral fracture of the humerus due to vitamin D deficiency showing elevated nitrogen levels, hyperlactatemia, elevated liver enzymes, hypermyoglobinemia, and leukocytosis

Parameter	Unit	Reference
Creatine kinase (CK)	479 U/L	21-232 U/L
Myoglobin	> 400 ng/dL	25-70 ng/dL
Creatinine	2.63 mg/dL	0.7-1.2 mg/dL
Urea	26.3 mg/dL	16.6-48.5 mg/dL
Lactate	8.1 mmol/L	0.5-1 mmol/L
Total bilirubin (TB)	4.16 mg/dL	0-1.2 mg/dL
Direct bilirubin (DB)	2.09 mg/dL	<0.20 mg/dL
Indirect bilirubin (IB)	2.08 mg/dL	0.2-0.8 mg/dL
Aspartate aminotransferase (AST/TGO)	115 U/L	10-50 U/L
Alanine aminotransferase (ALT/TGP)	65 U/L	10-50 U/L
Gamma-glutamyl transferase (GGT)	2110 U/L	8-61 U/L
Albumin	4.18 g/dL	3.97-4.9 g/dL
Lipase	34 U/L	13-60 U/L
Amylase	68 U/L	28-100 U/L
Lactic dehydrogenase (LDH)	278 U/L	135-225 U/L
Na	135 mmol/L	136-145 mmol/L
K	3.72 mmol/L	3.4-5.1 mmol/L
Cl	100 mmol/L	98-107 mmol/L
Phosphorus	2.52 mg/dL	2.5-4.5 mg/dL
Ionic calcium	0.86 mmol/L	1-1.3 mmol/L
Hemoglobin	13 g/dL	12.5-16 g/dL
Leukocytes	22.300/uL	5-10.5/uL
Neutrophils	20.400/uL	1500-6000/uL
Lymphocytes	668/uL	1000-3500/uL
Platelets	183.000/uL	150.000-400.000/uL
Prothrombin time	17.7 s	11.5-16.1 s
INR	1.33	0.85-1.3
Activated Partial Thromboplastin Time	33.3 s	24.3-38 s
Fibrinogen	291 mg/dL	200-400 mg/dL

Cl: chlorine; INR: international normalized ratio; K: potassium; Na: sodium.

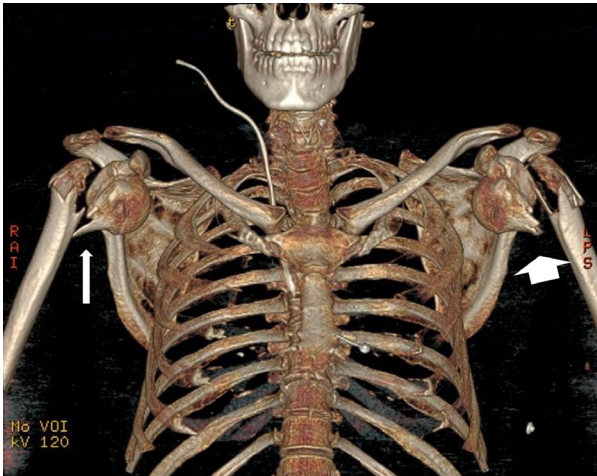


Figure 2. Chest three-dimensional computed tomography reconstruction. Bilateral distal metaphyseal multifragmentary fracture of the humerus (white arrow) with non-displaced fracture of the right coracoid process and fracture of the anterosuperior face of the right glenoid labrum. Source: Database, ICU Hospital Juárez de México, 2023.

an extremely important role in the absorption of calcium at the intestinal level, the maintenance of bones and teeth, as well as the normal functioning of muscles and the immune system.

Vitamin D is a generic term referring to both cholecalciferol (D3) and ergocalciferol (D2). The major circulating form routinely used to assess vitamin D status is 25-hydroxyvitamin (25-OHD), which reliably reflects the free fractions of the vitamin D metabolites. Even though the bioavailable fractions may be more clinically informative⁽⁵⁾.

The main function of vitamin D is to maintain a stable extracellular ionic calcium concentration through the stimulation of intestinal calcium absorption and the formation of mature osteoclasts that mobilize calcium from the bone to the extracellular space, which is key to the formation of new bone and correct bone metabolism⁽⁶⁾.

Vitamin D maintains an adequate blood phosphocalcium product that generates adequate bone mineralization. This is done through binding to the vitamin D receptor (VDR) on the enterocytes and osteoblasts. Without vitamin D, only 10–15 % of dietary calcium is absorbed, and up to 40.00 % if optimal levels of vitamin D are maintained. A low level of vitamin D stimulates the production of parathyroid hormone (PTH), which releases calcium from the bone, weakening it, to restore the levels of blood phosphocalcium product. This leads

to the fact that the levels of 25(OH)D are related to the mineral density, achieving a maximum bone density with levels of 40 ng/ml. From this, it follows that there is a directly proportional relationship between the levels of 25(OH)D reached and the anti-fracture efficacy⁽⁷⁾.

The clinical practice guidelines of the Endocrine Society Task Force on Vitamin D have defined a cutoff level of 30 ng/mL as vitamin D deficient. Although there is no consensus on optimal levels of 25(OH)D as measured in serum, vitamin D insufficiency is defined as 21–29 ng/mL, deficiency as less than 20 ng/mL, sufficiency as 30–60 ng/mL, and vitamin D intoxication with levels greater than 150 ng/mL. Levels of 30 ng/mL achieve adequate bone density and good muscle function in the lower extremities, as well as a reduction in the risk of falls, fractures, and colorectal cancer^(3,5,7). The most documented factors associated with vitamin D deficiency are: poorer functional capacity, older age, poor sun exposure, lower intake of fatty fish, poorer nutritional status, living alone, and being institutionalized⁽⁷⁾.

Specific categories of patients have a very high prevalence of vitamin D deficiency. Patients with chronic renal failure, on hemodialysis, renal transplant recipients, poor nutrition, liver disease, hyperthyroidism, granulomatous diseases, critical illness, and the use of medications such as anticonvulsants, immunosuppressants, and glucocorticoids may have a prevalence of vitamin D deficiency ranging from 85 % to 99 %. In patients with liver failure, there is a severe deficiency characterized by levels <7 ng/mL⁽⁵⁾. Available information about the association between alcohol use and vitamin D is still limited. It is suggested that low vitamin D serum levels in chronic alcoholics could be caused by malabsorption due to cholestasis or pancreatic insufficiency, poor dietary intake, lack of sunlight exposure, direct effects on vitamin D metabolism, impaired renal synthesis, and/or increased 1,25(OH)₂D degradation, as well as direct bowel mucosal lesions⁽⁴⁾.

There is moderate evidence for a positive association of vitamin D with bone mineral density and skeletal fragility. Low vitamin D status is associated with preferential atrophy of type II muscle fibers and influences signaling pathways that regulate inflammation in the skeletal muscle of elderly people at rest and following exercise. Inflammatory cytokines, such as tumor necrosis factor- α (TNF- α) and interleukin-6 (IL-6), can inhibit muscle protein synthesis and cause greater apoptosis in skeletal muscle. Therefore, vitamin D supplementation can improve muscle function and suppress the synthesis of C-reactive protein, TNF- α , IL-6, and the

previously described effects⁽⁸⁾. Approximately 85 % of the human skeleton is composed of compact (cortical) bone, demanding a great amount of calcium to mineralize the newly formed bone matrix, which is provided by vitamin D-dependent intestinal calcium absorption⁽⁹⁾.

In low-energy fractures with no obvious traumatic mechanism, a higher prevalence has been observed in patients with low levels of vitamin D, especially at the hip level. This is due to secondary hyperparathyroidism that occurs due to the lack of counter-regulation of vitamin D on PTH synthesis, a situation that leads to a considerable increase in bone resorption without adequate replacement of the mineralized matrix, ending in a significant reduction in bone resorption and resistance of this tissue⁽⁶⁾.

Stress fractures are the result of excessive stress on the bone due to prolonged and repetitive loading. The association between serum 25(OH)D levels and the occurrence of stress fractures has been previously documented in published studies, especially in military personnel (young and active military recruits). The addition of 2000 mg of calcium and 800 IU of vitamin D demonstrated a 20.00 % reduction in stress fracture incidence, and serum vitamin D levels greater than 40 ng/mL may be considered optimal for preventing stress fractures, especially for active patients with moderate to high functional demand^(10,11).

Regarding fractures caused by convulsive crises, there is little updated statistical information; however, some single-center studies report a hospital incidence of 1.1 %, of which 0.50 % presented fracture due to direct trauma, 0.30 % fracture as a consequence of the seizure only, and in 0.30 % the etiology was not documented. These data suggest that fractures secondary to seizures are infrequent, and even more so if they are not associated with trauma⁽¹²⁾.

Unless a person eats oily fish frequently, it is very difficult to obtain that much vitamin D3 daily from dietary sources. Sensible sun exposure can provide an adequate amount of vitamin D3, which is stored in body fat and released during the winter, when vitamin D3 cannot be produced. Exposure of arms and legs for 5 to 30 minutes between the hours of 10 a.m. and 3 p.m. twice a week is often adequate. Almost full exposure is equivalent to the ingestion of approximately 20,000 IU of vitamin D2. Excessive exposure to sunlight, especially sunlight that causes sunburn, will increase the risk of skin cancer. Thus, sensible sun exposure and the use of supplements are needed to fulfill the body's vitamin D requirement⁽³⁾.

It has been observed that the benefit in preventing fractures is with doses of vitamin D greater than 700–800 IU per day, which becomes relevant when considering that the vast majority of supplements on the market only provide 400 IU, so these doses could not prevent the risk of fractures⁽⁶⁾. The reduction in fractures within 6 months of commencing vitamin D supplementation is attributable to the benefits of 1,25(OH)D on muscle function, with a consequent reduction in falls⁽⁸⁾.

When a vitamin D deficiency has been diagnosed in the context of a fracture, vitamin D supplementation should be implemented to improve the body's osseous healing capability. The Endocrine Society has suggested that adults with vitamin D deficiency, regardless of the presence of a fracture, should supplement with 50,000 IU of vitamin D2 or vitamin D3 once a week for 4 to 8 weeks or its equivalent of 6000 IU daily to achieve a 25(OH)D level >30 ng/mL and until fracture healing has occurred. Repeat serum 25(OH)D measurements should be taken every 3 months or after the patient's treatment course. If adequate levels have been met, the patient should be advised to continue with a lower maintenance supplementation dose of 2000 IU daily to prevent the recurrence of a stress fracture^(1,10).

The severity of the deficiency and dose required for treatment will determine the frequency of blood determination for efficacy and safety⁽¹⁾.

Regarding the history of alcoholism, it should be noted that the levels of serum concentration of vitamin D are 28.00 % lower in alcoholics than in non-alcoholics and up to 64 %-92 % in patients with cirrhosis, due to malabsorption caused by cholestasis or pancreatic insufficiency, poor dietary intake, lack of sunlight exposure, impaired renal synthesis, increased 1,25(OH)2D degradation, and direct bowel mucosal lesions. Hypovitaminosis D is an independent risk factor for sarcopenia and osteoporosis in patients with chronic liver disease and, therefore, the risk of fracture^(13,14).

Vitamin D deficiency is highly prevalent, but the literature to support vitamin D supplementation is unsatisfactory to date. Unless major funding sources are used for vitamin D research, it appears sensible to focus on vitamin D-deficient populations with a high event rate. Vitamin D is not a panacea but may be an important, inexpensive, and safe adjuvant therapy for many diseases and stages of life, including pregnancy, childhood, and advanced old age. Public health efforts to prevent severe vitamin D deficiency should, therefore, be further promoted.

Vitamin D deficiency is common and often unrecognized, yet it can play an important role in exacerbating underlying pathologies, especially in vulnerable populations and in association with low PTH levels. However, cortical bone loss is associated with bone turnover and vitamin D levels, but not always with PTH levels, as evidenced in this case.

Proximal humeral fractures are common among elderly patients, but not in the young, and less so in the absence of trauma. Most fractures are the result of a fall onto an overextended arm, less frequently from a direct blow. In this case, despite the episode of convulsive crisis, no trauma was documented; however, there was a vitamin D deficiency as a condition for bone fragility.

Regardless of the surgical treatment involved in the fracture, immediate vitamin D supplementation should be performed to improve bone healing capacity and not underestimate the importance of this micronutrient that impacts the osteomuscular level.

CONCLUSIONS

This clinical case demonstrates the relevance that vitamin D has for the body, having an important role in the absorption of calcium at the intestinal level as well as in the proper functioning of bones, teeth, muscles, and the immune system. The serious consequences of this fat-soluble vitamin deficiency can lead to pathological fractures at ages where these should not occur, and therefore the doctor must be able to suspect its deficiency for an adequate diagnosis and short- and long-term treatment.

It is important to consider the risk factors for vitamin D deficiency: chronic renal failure, hemodialysis, renal transplant receptors, poor nutrition, liver disease, hyperthyroidism, granulomatous diseases, critical disease, and drugs such as anticonvulsants, immunosuppressives and glucocorticoids.

Vitamin D supplementation improves muscle function and suppresses the synthesis of C-reactive protein, TNF- α , IL-6, and the apoptotic effects that it entails.

The proximal humerus fractures are common among elderly patients, but not in young people, and less in the absence of trauma. In low-energy fractures without obvious traumatic mechanisms, greater prevalence has been observed in patients with low vitamin levels.

For the surgical treatment involved in the fracture, an immediate vitamin D supplementation should be performed to improve the bone healing capacity and not underestimate the importance of this micronutrient that impacts at the osteomuscular level.

Acknowledgments

To the entire team of the intensive care unit of Hospital Juárez de México.

Declaration of authorship

Amezcu-Gutierrez and Medveczky-Ordoñez equally contributed to the conception and design of the research; Amezcu-Gutierrez, Medveczky-Ordoñez, and Garduño-Lopez contributed to the research design; Lopez-Rodriguez and Gasca-Aldama contributed to data acquisition and analysis; Rodriguez-Villanueva, Vidals-Sánchez and Guevara-Cruz contributed to the interpretation of the data; and Amezcu-Gutierrez, Medveczky-Ordoñez, and Garduño-Lopez drafted the manuscript. All authors reviewed the manuscript, agree to be fully responsible for ensuring the completeness and accuracy of the paper, and have read and approved the final manuscript.

Conflict of interest

The authors declare that they have no conflicts of interest.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

Ethical disclosures

- Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.
- Confidentiality of data. The authors declare that no patient data appears in this article.

References

1. Berger MM, Shenkin A, Schweinlin A, Amrein K, Augsburger M, Biesalski HK, et al. ESPEN micronutrient guideline. *Clinical Nutrition*; 2022;41(6):1357-1424. doi: 10.1016/j.clnu.2022.02.015
2. Mendes MM, Gomes APO, Araújo MM, Coelho ASG, Carvalho KMB, Botelho PB. Prevalence of vitamin D deficiency in South America: a systematic review and meta-analysis. *Nutr Rev* 2023;81(10):1290-1309. doi: 10.1093/nutrit/nuad010
3. Holick MF. Vitamin D deficiency. *N Engl J Med*. 2007;357(3):266-81. doi: 10.1056/NEJMra070553
4. Tardelli VS, Lago MPPD, Silveira DXD, Fidalgo TM. Vitamin D and alcohol: A review of the current literatura.

- Psychiatry Research. 2017;248:83–6. doi: 10.1016/j.psychres.2016.10.051
5. Amrein K, Scherkl M, Hoffmann M, Neuwersch-Sommeregger S, Köstenberger M, Tmava Berisha A, et al. Vitamin D deficiency 2.0: an update on the current status worldwide. *Eur J Clin Nutr.* 2020;74(11):1498-1513. doi: 10.1038/s41430-020-0558-y
 6. Donoso M. R, Román V. J. Vitamina D: ¿qué es lo que debe saber un traumatólogo? *Rev Chil Ortop Traumatol.* 2016;57(2):64-8. doi: 10.1016/j.rchot.2016.07.004
 7. Marañón E, Omonte J, Álvarez ML, Serra JA. Vitamina D y fracturas en el anciano. *Rev Esp Geriatr Gerontol.* 2011;46(3):151–62. doi: 10.1016/j.regg.2011.01.005
 8. Sanders KM, Scott D, Ebeling PR. Vitamin D deficiency and its role in muscle-bone interactions in the elderly. *Curr Osteoporos Rep.* 2014;12(1):74-81. doi: 10.1007/s11914-014-0193-4
 9. Paranhos-Neto FP, Vieira Neto L, Madeira M, Moraes AB, Mendonça LMC, Lima ICB, et al. Vitamin D deficiency is associated with cortical bone loss and fractures in the elderly. *Eur J Endocrinol.* 2019;181(5):509-17. doi: 10.1530/EJE-19-0197
 10. Miller JR, Dunn KW, Ciliberti LJ Jr, Patel RD, Swanson BA. Association of Vitamin D With Stress Fractures: A Retrospective Cohort Study. *J Foot Ankle Surg.* 2016;55(1):117-20. doi: 10.1053/j.jfas.2015.08.002
 11. Knechtle B, Jastrzębski Z, Hill L, Nikolaidis PT. Vitamin D and Stress Fractures in Sport: Preventive and Therapeutic Measures-A Narrative Review. *Medicina.* 2021;57(3):223. doi: 10.3390/medicina57030223
 12. Finelli PF, Cardi JK. Seizure as a cause of fracture. *Neurology.* 1989; 39(6):858-60. doi: 10.1212/wnl.39.6.858
 13. Tadokoro T, Morishita A, Himoto T, Masaki T. Nutritional Support for Alcoholic Liver Disease. *Nutrients.* 2023;15(6):1360. doi: 10.3390/nu15061360
 14. Uzdziński AW, Zych A, Świerad BA, Wawrzynowicz-Syczewska M. The role of vitamin and microelement supplementation in the treatment of ethanol-induced liver disease. *Prz Gastroenterol.* 2022;17(4):253-6. doi: 10.5114/pg.2022.121820