von Hippel-Lindau syndrome-related congenital polycythemia and response to belzutifan

von Hippel-Lindau (VHL) syndrome is an inherited, autosomal dominant disease with an estimated incidence of 1 in 36,000 live births.[1] It is characterized by a wide spectrum of benign and malignant tumors such as craniospinal hemangioblastomas, retinal capillary hemangioblastomas, clear cell renal carcinoma (RCC), pancreatic neuroendocrine tumors (pNET), pheochromocytomas, middle ear endolymphatic sac tumors, and epididymal cystadenomas.[2] An atypical clinical manifestation of VHL is the Chuvash erythrocytosis (CE), a congenital polycythemia, provoked by a homozygotic 598C>T (R200W) mutation in the *VHL* gene located on chromosome 3p25.[3] This syndrome can present with plethora, fatigue, and headache. Cohort studies suggest an associated trend towards higher mortality in CE patients due to an elevated incidence of peripheral and central nervous and vascular system thromboses including stroke, myocardial infarction, pulmonary embolism.[4,5] The VHL protein normally interacts with the E3 ubiquitin complex, disrupting proteolysis of hypoxia-inducible factor α (HIFα). Therefore, the pathogenesis of CE occurs with the loss-of-function of *VHL* leading to a pseudohypoxic state and accumulation of HIF-1α and 2α causing further activation of genes responsible for angiogenesis, cycle-cell progression and erythropoiesis.[6,7]

In this context, belzutifan emerges as a novel class of anti HIF2α agents, inhibiting the transcription of HIF2 α-sensitive genes. The efficacy of belzutifan on *VHL*-associated neoplasm was reported by Jonasch and colleagues showing an objective response of 59%, 90%, and 38% in RCC, pNET and central nervous system (CNS) hemangioblastomas, respectively.[8] Consequently, it exhibits antitumor activity and concurrently reduces plasma erythropoietin levels, which potentially elucidates the mechanism leading to a decline in hemoglobin levels.[9,10] Here, we report a patient with congenital polycythemia (CP) who was treated with belzutifan, response and tolerance of treatment. The research was conducted under Institutional Review Board-approved protocol 160979.

A 30-year-old female was referred to our clinic due to polycythemia. Her elevated hematocrit had been known since birth, and she had undergone therapeutic phlebotomies for chronic headaches and fatigue since puberty, which had recently failed to relieve her symptoms or to reduce her hematocrit. Genetic analysis found two heterozygous germline mutations on the *VHL* gene: the Chuvash documented R200W (c598C>T) as well as L118V (c562C>G). At presentation, her complete blood count (CBC) revealed a red blood cell (RBC) count of 7.83 x 10^{12}/L (4.04 - 5.48), hemoglobin (Hb) of 19.0 g/dL (11.8 - 16.0), hematocrit (HCT) of 63.8% (37.7 - 47.9) and erythropoietin (EPO) levels of 138 mIU/mL (3 – 19) (Table 1). Her VHL-related screening included abdominal, CNS and spine MRI, audiometry and ophthalmological evaluation, and metanephrine levels, all of which were unrevealing. Her family history was not known.

In March 2022, belzutifan 120 mg daily was started with a decrease in her Hb at four weeks to 17.0 g/dL and at eight weeks her Hb normalized at 13.0 g/dL. After 16 weeks of treatment, her Hb reduced to 9.4 g/dL resulting in grade 2 anemia and the belzutifan dose was reduced to 80 mg which she remains with normalization of Hb and EPO levels (Figure 1). Chuvash erythrocytosis, a rare manifestation of *VHL* disease, is caused by homozygous R200W. However, *VHL* heterozygous biallelic mutations have also been implicated in congenital polycythemia. Pastore *et al.*[11] documented a case series involving 7 patients with *VHL* mutations and polycythemia: 3 with homozygous VHL^{R200W} mutations, 3 heterozygous VHL^{R200W} mutations (including 2 with VHL^{R200W} and VHL^{L188V} mutations similar to our patient), and one with homozygous VHL^{H191D} mutation. Our patient's baseline Hb and EPO levels were above the median values typically reported in patients with CE.[3,4] However, it is important to note that there is a wide range of measurements in these cases. Specifically, in two patients with the same $VHL^{R200W/L188V}$ genotype as our patient, Hb levels ranged from 16.3 g/dL to 21.0 g/dL. This variability highlights the challenge of making comparisons among patients with rare and heterogeneous conditions. Historically, the data on management are limited and have included the controversial use of phlebotomies. A study by Gourdauk *et al.*[5] did not find a clear association between high hematocrit levels and an increased incidence of thrombotic events. Instead, patients with history of therapeutic phlebotomy appeared to be at higher risk for thrombosis due to the impact on iron

Table 1. Baseline levels of erythropoietin (EPO), hemoglobin (Hb) and hematocrit (HCT) and its variation during treatment

	Week 0	Week 4	Week 8	Week 16	Week 40	Week 98
EPO, mIU/mL	138	-	-	-	-	4
Hb, g/dL	19.0	17.0	13.0	9.4	13.4	14.2
HCT, %	63.8	54.0	41.0	28.0	39.0	43.0

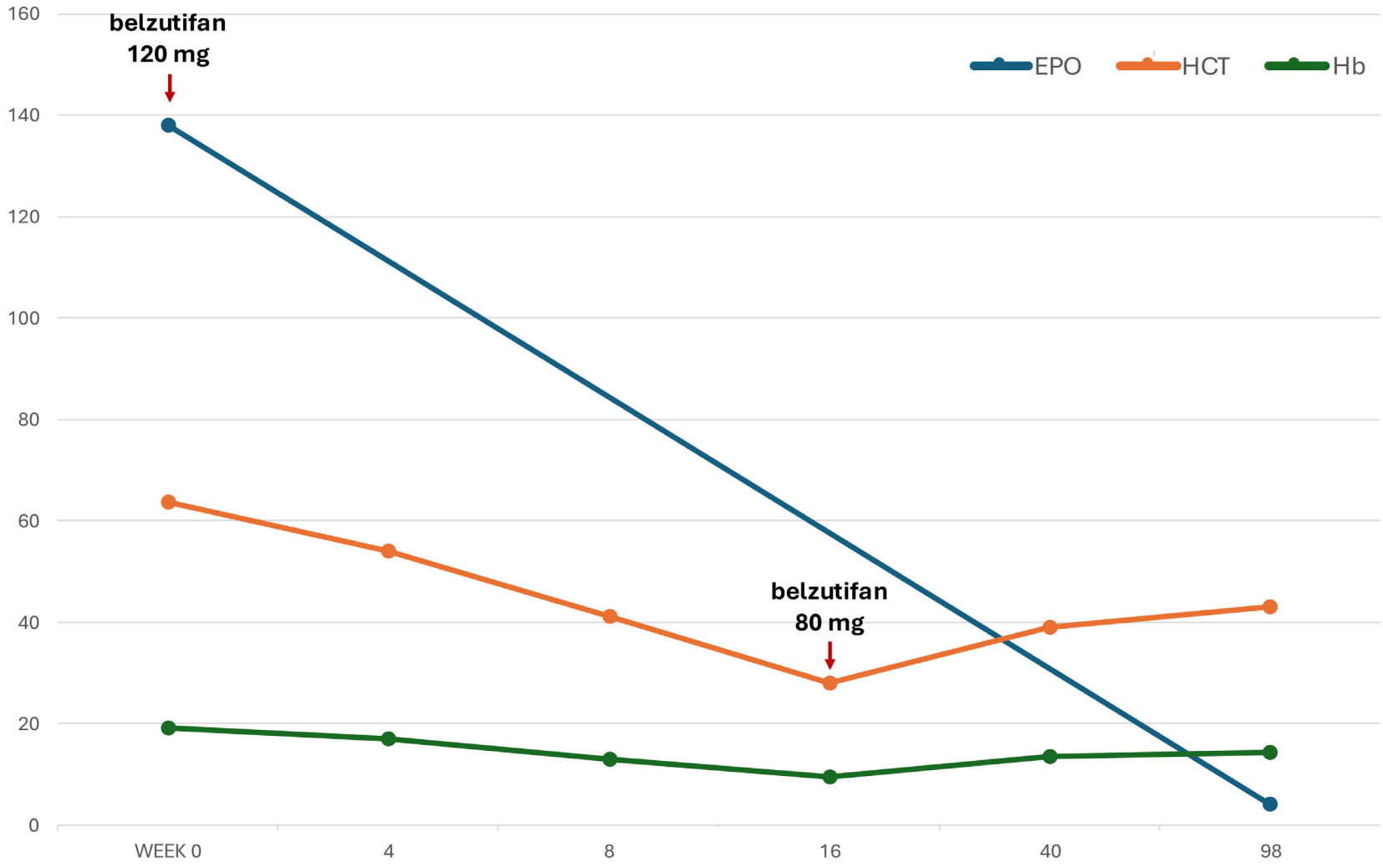

Figure 1. Patient with *von Hippel-Lindau* syndrome-related congenital polycythemia: laboratory evaluation and response to belzutifan. Dosing and response over time in weeks for decreased red blood cells measured by hematocrit (HCT, %) and hemoglobin (Hb, g/dL), as well as initial and final erythropoietin (EPO, mIU/mL) levels.

storage, which can culminate in a cyclical elevation of HIF and EPO levels.[12] Aspirin has been shown to reduce risk of acute myocardial infarction, non-fatal strokes, or death from cardiovascular disease in patients with polycythemia vera (PV), but it has not been prospectively tested in CE patients. A Janus kinase (JAK) 1 and 2 inhibitor, ruxolitinib, is often used in the management of patients with PV. Unlike CE, PV is characterized by mutations in the *JAK2* gene. Nonetheless, the use of JAK-2 inhibitors decreased hematocrit levels in mouse models carrying the *VHL*^{R200W} mutation.[13] Building on this rationale, Zhou *et al.*[14] evaluated the use of ruxolitinib in 3 patients with CE, reporting improved symptoms and a reduction in the frequency of phlebotomies.

In 2021, in a phase II trial, Jonasch *et al.*[8] reported the significant efficacy and safety of belzutifan in patients with *VHL* disease and renal cell carcinoma with notable objective responses in RCC, CNS hemangioblastomas and pancreatic tumors. Notably, anemia was the most common adverse event, affecting 90% of patients, which reinforces the impact of belzutifan on erythropoiesis. Also, prior research in *VHL*^{R200W} homozygous murine models demonstrated elevated EPO levels that decreased upon initiation of oral belzutifan, led to the reversal of polycythemia, and reduced pulmonary hypertension.[15] In our case, the patient achieved normal hemoglobin and hematocrit levels following belzutifan treatment, with a rapid and well-tolerated response, even at a reduced dose of belzutifan. While a standard treatment for CE remains elusive, belzutifan appears to be a promising, efficient, and safe tool for the management of that condition. Prospective studies with extended follow-up are needed to evaluate clinical outcomes such as improvement of symptoms, reduction of cardiovascular events and the need for phlebotomies, and the development of treatment resistance. Furthermore, it is important to address other risk factors, such as tobacco smoking and hypertension, and maintain regular follow-up and genetic counseling due to potential associations with other conditions related to *VHL* syndrome.

In conclusion, this case report is the first to highlight the activity and safety of belzutifan in a patient with *VHL*-related polycythemia, suggesting a path for future prospective trials and discussion with global regulatory agencies.

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Contributions

All authors reviewed data, and wrote and revised the manuscript.

Data-sharing statement

All available data are presented in the text and figure of this case report. Additional requests for information can be made to the corresponding author.

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