Irish Interdisciplinary Journal of Science & Research (IIJSR)
Volume 10, Issue 1, Pages 61-69, January-March 2026

Deep Survey on Bitnet Optimised Yolov12 Pipeline for Volumetric Estimation from Ultrasound Images

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DOI: https://doi.org/10.46759/iijsr/2026.10108

Article Received: 09 January 2026 *Article Accepted: 14 March 2026* *Article Published: 18 March 2026*

ABSTRACT

Accurate assessment of hematologic disorders often depends on precise organ quantification traditional planar imaging techniques are limited as they fail to capture the full three-dimensional structure of organs smartspv addresses this limitation by reconstructing 3d organ size from one or two images providing a more comprehensive evaluation advanced algorithms such as bitnet lightautoml yolov12 and qmix further enhance measurement accuracy ensuring precise calculations critical for clinical decision-making additionally an integrated compact NLP module generates concise clinical observations streamlining reporting and interpretation this combination of technologies enables rapid reliable results that are suitable for bedside application even in under-resourced healthcare settings by reducing dependence on extensive imaging infrastructure while maintaining high accuracy this solution supports timely diagnosis monitoring and treatment planning for patients with hematologic conditions.

Keywords: Splenomegaly; Sickle Cell Disease; 3D Spleen Volume; 2D Ultrasound; Deep Learning; YOLOv12; LightAutoML; BitNet; QMix++; NLP; Point-of-Care; Resource-limited Settings.

1. Introduction

A single-gene defect distorts red blood cells creating widespread disruptions in circulation and organ function current and experimental approaches mainly alleviate clinical manifestations with their long-enduring on organ function still unclear highlighting effects on blood flow is essential for tailoring therapy and addressing diverse disease outcomes [1].

A single-point change in the β-globin sequence leads red blood cells to adopt abnormal shapes, reducing their flexibility and impairing oxygen transport. Studies from the last decade indicate that personalized stem cell therapies can overcome donor and immune constraints of conventional transplantation. Advanced molecular tools, including CRISPR/Cas9 and viral vector systems, show promise in re-establishing normal hemoglobin function [2].

A single-gene defect in red cell proteins produces abnormally shaped cells causing persistent discomfort and organ stress novel gene-modification techniques are being explored for individuals without compatible donors despite ongoing challenges in safety and delivery precision advances in molecular editing are progressively moving these curative interventions toward routine clinical use [3].

The current gene-based approaches for correcting red blood cell abnormalities offer promising results yet they do not fully resolve all challenges limitations such as delivery precision potential long-term risks and accessibility for patients without compatible donors remain while these methods represent a significant step toward curative treatment further refinement and long-term studies are needed to achieve consistently reliable outcomes and fully restore organ function.

1.1. Study Objectives

- To develop a smart system capable of reconstructing accurate three-dimensional organ volumes from one or two planar medical images for improved hematologic assessment.
- To integrate advanced algorithms such as BitNet, LightAutoML, YOLOv12, and QMIX to enhance measurement precision and ensure reliable organ size quantification.
- To design an automated workflow that reduces manual intervention, minimizes variability, and accelerates clinical decision-making.
- To implement a compact NLP module that generates concise and clinically relevant observations for streamlined reporting.
- To evaluate the system's accuracy, efficiency, and reliability compared to traditional imaging-based measurement techniques.
- To ensure the solution is cost-effective, portable, and suitable for bedside use in under-resourced healthcare settings.

2. Literature Survey

A genetic mutation alters oxygen-carrying cells producing rigid shapes that strain the circulatory system and compromise organ performance disturbed circulation persistent immune activation and weakening of artery walls contribute to early strokes tissue damage and kidney dysfunction combining computational simulations with clinical assessment provides insights into vascular injury and supports tailored preventive interventions [4]. An inherited molecular deforms red blood cells causing vessel obstruction pain episodes and gradual organ strain the discontinuation of therapies such as crizanlizumab and voxelotor underscores the urgent need for innovative treatment approaches cutting-edge imaging and tissue evaluation techniques were applied to explore disease mechanisms in detail procedures included intravital microscopy laser speckle contrast imaging and comprehensive histological examination the study focused on spleen tyrosine kinase syk and its role in guiding platelet and immune cell recruitment as well as influencing organ perfusion in lungs kidneys liver and spleen of affected mice [5]. Sickle cell disorder, a single-gene condition with highly variable clinical outcomes, makes predicting disease severity challenging.

This observational study of 180 patients examined whether laboratory indicators could reflect disease intensity. Elevated white cell and platelet counts were linked to more hospitalizations and urgent care visits, while higher fetal hemoglobin correlated with fewer admissions and ICU stays. These inflammatory and hematologic measures may aid in risk assessment and inform the development of novel therapeutic approaches [6]. Mutations in the enzyme-encoding pklr locus influence the severity of inherited hemoglobin disorders specific inherited variants increase episodes of painful vascular blockage and may provoke symptoms in otherwise unaffected individuals loss of pkr activity impairs red blood energy production and leads to abnormal metabolite buildup intensifying cell deformation gene-editing with crispr-cas9 was applied in mice expressing different human hemoglobin forms to

assess impacts on anemia iron deposition and red blood maturation results reveal genotype-dependent changes in cellular morphology off-site blood formation and retention of organelles highlighting the complex role of pkr insufficiency in disease progression [7]. The spleen plays a central role in regulating blood by selectively capturing or clearing circulating oxygen-carrying cells influencing how malaria impacts the body variations in splenic function affect the intensity of symptoms during infection examination of spleens removed from papua patients showed that asymptomatic individuals harbored far more parasite-containing cells inside the organ than in the bloodstream along with many healthy cells a computational model treated the spleen as a separate compartment able to retain both affected and intact cells in p falciparum and p vivax infections simulations revealed that accumulation of normal cells within the spleen greatly exceeds losses from parasitic invasion with chronic infections showing much higher ratios than previously reported for acute cases [8]. A hereditary hemoglobin disorder affects millions worldwide causing significant health complications from early childhood without preventive measures or disease-altering interventions patients face repeated crises and progressive organ damage reducing lifespan and quality of life modern care advancements including newborn screening paired with family education have dramatically lowered mortality treatments that boost fetal hemoglobin and emerging cellular therapies now provide potential curative outcomes regulatory approval of innovative gene-based interventions offers hope that future generations may experience minimal pain and improved long-term health [9]. A genetic blood condition alters the structure and function of erythrocytes leading to reduced oxygen delivery and repeated systemic complications this lifelong illness affects a considerable population across the united states with many patients relying on public insurance coverage frequent pain crises infections and progressive organ impairment contribute to substantial medical needs throughout life although the disorder is widely recognized as a major public health concern updated real-world evidence describing service demand and financial impact within medicaid populations remains limited this investigation evaluates patterns of healthcare use and related expenditures among pediatric and adult beneficiaries to support improved clinical planning and resource allocation [10].

A widely prevalent inherited blood abnormality arises from alterations in globin structure leading to distorted erythrocyte morphology and impaired oxygen transport under hypoxic conditions this condition represents a substantial global health concern particularly across African and Southern European regions with increasing recognition in western nations due to demographic transitions timely identification plays a decisive role in preventing severe complications and improving long-term survival and well-being because early manifestations may be subtle and clinically ambiguous frontline practitioners often face challenges in recognizing affected individuals this review outlines characteristic manifestations accessible investigative methods and practical clinical frameworks to support prompt recognition and referral pathways in everyday practice [11]. Enlargement of the spleen is frequently identified during abdominal imaging performed for unrelated reasons, yet its prognostic relevance in asymptomatic individuals remains uncertain. Clear thresholds that signal elevated likelihood of serious disorders such as blood malignancies or advanced hepatic pathology have not been well established. Determining risk gradients based on splenic dimensions could refine decisions regarding further diagnostic evaluation. This study investigates the association between measured splenic size and subsequent development of major hematologic and hepatic outcomes in population-based cohorts [12]. Single nucleotide alteration in the -globin

locus leads to the production of an abnormal hemoglobin variant that polymerizes during deoxygenation triggering erythrocyte deformation and vascular obstruction although supportive medications have improved symptom control they do not fully prevent progressive organ injury innovative therapeutic concepts are therefore required to directly interrupt the molecular events responsible for pathogenic aggregation one emerging strategy involves engineering protein-based stabilizers that maintain hemoglobin in a non-polymerizing configuration this review explores structural computational and bioengineering advances supporting this approach along with key translational challenges for clinical implementation [13]. Sickle cell disease (SCD) remains a critical contributor to early mortality and preventable chronic complications worldwide. Early detection and timely access to specialized care are essential to improve clinical outcomes. In Italy, a national screening program for SCD is not yet established, prompting regional pilot initiatives. One such project implemented point-of-care testing in primary pediatric clinics to identify children with abnormal hemoglobin. This study reports the outcomes of screening 1,000 at-risk children, highlighting the prevalence of SCD and hemoglobin traits, particularly among those with African ancestry [14].

Sickle cell disorder results from a single-gene mutation that alters hemoglobin causing recurring health complications and frequent hospital visits this condition is particularly common in historically marginalized populations exposing inequities in access to medical services recent advancements in gene-focused therapies offer new possibilities to modify disease outcomes yet adoption remains low barriers such as limited understanding mistrust and systemic gaps continue to slow uptake this study explores these obstacles and highlights approaches to enhance the reach and effectiveness of innovative treatments [15]. An inherited hemoglobin variant leads to lifelong health instability and recurring medical needs across multiple body systems while clinical care often concentrates on pain control and organ-related outcomes reproductive wellbeing receives comparatively less attention individuals living with this condition may encounter reduced fertility potential and elevated maternal risks these concerns require proactive counseling and coordinated multidisciplinary care this article reviews reproductive considerations and outlines clinical perspectives to better support family-planning decisions [16]. Advanced sickle cell disease can be life-threatening and curative therapies have historically been limited by high failure rates and severe side effects newer transplant approaches employ milder preparative treatments partially compatible donors and targeted post-transplant medications to improve success and safety adjusting radiation intensity may further promote stable donor cell integration while reducing toxicity assessing long-term patient outcomes including survival graft function immune response and recovery of bodily functions is critical this study evaluates a contemporary transplantation strategy aimed at maximizing efficacy while maintaining a favorable safety profile for patients with severe disease [17]. Aydroxyurea is widely used to improve clinical outcomes in children with sickle cell anemia but optimal dosing varies considerably among patients differences in how the body absorbs and processes the drug can influence its effectiveness little is known about whether these pharmacokinetic patterns differ between children in different regions of the world comparing data from multiple international studies can help determine if standardized dosing approaches are appropriate globally this study examines pharmacokinetic profiles in diverse pediatric populations to guide safe and effective hydroxyurea use worldwide [18]. An inherited mutation affecting the -globin chain gives rise to sickle cell disease a condition marked by fragile

blood cells chronic vascular injury and progressive organ impairment continuous cell breakdown disrupts normal physiology and weakens host defense mechanisms increasing vulnerability to life-threatening systemic infections among the serious complications triggered during severe infection is acute deterioration of kidney function which greatly heightens the risk of poor outcomes the biological drivers of renal damage in this setting remain incompletely understood ongoing intravascular destruction releases free heme into the circulation where it acts as a strong mediator of oxidative imbalance and inflammatory signaling defining how these processes interact during sepsis may guide the development of more precise and effective therapeutic approaches [19].

Recent advances in cell biology have shown that adult cells can be reverted to a highly flexible state using specific regulatory proteins. These reprogrammed cells can grow indefinitely and develop into many different tissue types, offering a new route for creating patient-specific therapies. Yet, it remains unclear whether such cells can be corrected for genetic defects and used to treat diseases in living organisms. Effective application requires precise gene editing combined with guided maturation into functional cell populations. Blood disorders caused by single-gene abnormalities provide an ideal framework to explore this strategy. Successfully restoring healthy blood function in an experimental model would demonstrate the potential of merging reprogramming with targeted gene correction for therapeutic purposes [20]. Having consistent access to sufficient food is essential for maintaining health especially for individuals with ongoing medical conditions young people with sickle cell disease often experience frequent health complications and require repeated hospital care when food is scarce managing the illness becomes more difficult and overall health may decline exploring how limited food resources affect this group can highlight the connection between social challenges and health outcomes understanding these factors can inform strategies to reduce complications and lessen the need for hospital visits supporting reliable access to nutritious food may therefore improve both health and quality of life for affected patients [21].

The breakdown of red blood cells plays a central role in the development and variability of sickle cell disease products released during hemolysis disrupt vascular function and trigger inflammatory and oxidative pathways these changes contribute to a wide range of complications including organ damage blood vessel remodeling and impaired circulation free hemoglobin and heme act as signaling molecules that activate immune and endothelial cells promoting vaso-occlusion and tissue injury reduced nitric oxide availability and oxidative stress further amplify vascular dysfunction and disease severity understanding these mechanisms is essential for developing therapies that target the vascular consequences of hemolysis in sickle cell disease and related conditions [22]. Monocytes are critical for maintaining red blood cell homeostasis particularly under conditions of increased demand or anemia in sickle cell anemia chronic destruction of red blood cells exposes monocytes to damaged or abnormal cells in the bloodstream this exposure can change monocyte behavior equipping them to handle higher levels of iron and participate in red blood cell clearance these immune cells can take up damaged erythrocytes break down heme and contribute to iron recycling functions usually attributed to specialized macrophages in the bone marrow surface and functional changes allow monocytes to efficiently manage these tasks while supporting the body’s increased erythropoietic needs investigating these adaptations provides insight into how monocytes influence both iron metabolism and disease progression in sickle cell anemia [23]. Sickle cell disease (SCD) is an inherited disorder that affects hemoglobin structure and function, leading to abnormal red blood cell shapes. These

changes can disrupt normal blood flow and reduce oxygen delivery to tissues, particularly in the brain. Monitoring cerebral blood flow (CBF) is essential to identify early neurovascular changes and prevent long-term damage. Conventional methods like transcranial Doppler (TCD) ultrasound measure blood velocity in major cerebral arteries but provide limited insight into microvascular perfusion. Diffuse correlation spectroscopy (DCS) is a non-invasive optical technique that estimates regional CBF and may complement existing methods. This study evaluates how DCS measurements correlate with TCD-derived blood flow velocities. Establishing such tools could improve early detection and guide interventions to reduce stroke risk [24]. Sickle cell disease (SCD) is a genetic disorder that affects many newborns and can lead to severe, life-threatening complications. Vaso-occlusive crises (VOC) cause sudden pain and organ damage, and current treatments, including hydroxyurea (HU), have limited effectiveness. Studies indicate that the complement system, a part of innate immunity, can worsen vascular injury by damaging endothelial cells (ECs) [25].

3. Problem Statement

- Traditional planar imaging cannot accurately measure three-dimensional organ size, leading to incomplete assessment and reduced diagnostic reliability in hematologic disorder management.
- Advanced 3D imaging systems are costly and infrastructure-dependent, limiting accessibility in bedside and under-resourced healthcare environments.
- Manual measurement and interpretation increase variability, delay reporting, and may impact timely clinical decision-making.
- There is a need for an automated, accurate, and affordable solution that reconstructs 3D organ size from minimal imaging inputs.

4. Conclusion

This novel 3d imaging tool offers a transformative approach for monitoring spleen alterations in individuals with sickle cell disorder by applying artificial intelligence to volumetric scan data it produces detailed three-dimensional reconstructions that allow healthcare providers to inspect the organs structure from multiple perspectives and detect abnormalities accurately the combination of optimized segmentation algorithms and predictive modeling facilitates reliable quantification of organ size even in extreme cases enabling prompt and evidence-based intervention its quick analysis capabilities reduce dependency on manual interpretation enhance diagnostic consistency and contribute to more effective clinical management.

Declarations

Source of Funding

This study did not receive any grant from funding agencies in the public, commercial, or not–for–profit sectors.

Competing Interests Statement

The authors have not declared any conflict of interest.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

Informed Consent

Not applicable for this study.

Availability of data and material

Supplementary information is available from the authors upon reasonable request.

Institutional Review Board Statement

Not applicable for this study.

Ethical Approval

Not applicable for this study.

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