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Review Article

Incidence and prevalence of sickle cell trait and disease in Madhya Pradesh, with special reference to Eastern Madhya Pradesh and Singrauli district

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ABSTRACT

Madhya Pradesh carries one of the largest burdens of sickle cell disease (SCD) in India, concentrated largely among its scheduled tribe, scheduled caste, and other backward class communities. This article synthesises published epidemiological and clinical data on sickle cell trait and disease in Madhya Pradesh, with particular attention to the eastern districts of the state-including Singrauli, Sidhi, Shahdol, Rewa, and Anuppur-where tribal concentration and endogamous marriage practices sustain a high carrier frequency. Demographic data from the 2011 Census are used to contextualise the disease burden in Singrauli district, and district-level screening trends are discussed alongside the clinical and haematological profile of sickle cell anaemia (SCA) and sickle-beta thalassaemia (SBT) reported from Central India. In addition, four years (2022-2025) of institutional high-performance liquid chromatography (HPLC)- and solubility-based screening data from the Department of Pathology, District Hospital, Singrauli are presented and interpreted in light of the referral-biased, non-population-representative nature of hospital-based testing.

Keywords: Sickle cell disease, Madhya Pradesh, Review

INTRODUCTION

Sickle cell disease (SCD) is an autosomal recessive haemoglobinopathy caused by a point mutation in the beta-globin gene, producing haemoglobin S (HbS). In India, the disease is concentrated among tribal and other socio-economically disadvantaged populations of central, western, and southern India, with carrier prevalence among tribal groups nationally ranging from about 1 to 40%.[1-3] Madhya Pradesh, home to the country's largest tribal population, bears the single largest state-level burden of sickle haemoglobin in India.

BURDEN OF SICKLE CELL TRAIT AND DISEASE IN MADHYA PRADESH

Madhya Pradesh has been estimated to carry approximately 9,61,492 sickle cell heterozygotes (trait carriers) and 67,861 sickle cell homozygotes (disease)-the highest absolute load of any state in the country.[4] Of the state's 45 districts, 27 fall within what is described as the "sickle cell belt," where HbS prevalence fluctuates between roughly 10 and 33 per cent depending on the community screened. On this basis, it has been projected that around 13,432 pregnancies annually in the state carry a genetic risk for SCD, translating to an estimated 3,358 births of sickle-homozygous (HbSS) infants each year.[4] These figures, drawn from tribal-health research in the state, underline why Madhya Pradesh has become a national priority area for the Government of India's mission to eliminate SCD as a public health problem.

The largest tribal groups affected in central India are the Gond and Bhil communities, along with smaller groups such as the Kol, Baiga, and Korku. A long-term clinical registry maintained at a tribal-health research institute in

Jabalpur, which followed 776 sickle cell patients from 2000 to 2014, found that scheduled caste communities (such as Jharia, Mehra, and Deharia groups) accounted for the largest proportion of registered patients (47.9%), followed by Other Backward Classes such as Lodhi, Kurmi, and Yadav communities (28.4%), with the Gond scheduled tribe constituting 13.8% of patients, the remainder being Muslim and Brahmin families.[1,4] This pattern reflects the fact that sickle haemoglobin in Madhya Pradesh is not confined to tribal groups alone but is widely distributed among historically endogamous communities across the caste spectrum, a finding consistent with the broader observation that consanguineous and endogamous marriage customs sustain high carrier frequencies in these populations.

EASTERN MADHYA PRADESH: A HIGH-PREVALENCE SUB-REGION

Within the state's sickle cell belt, the eastern districts-Singrauli, Sidhi, Shahdol, Anuppur, Umaria, Rewa, Satna, and neighbouring Chhindwara, Balaghat, Seoni, Mandla, Betul, Narmadapuram, and Raisen-carry a disproportionate share of the tribal population and, correspondingly, of sickle gene carriers. Madhya Pradesh has the highest tribal population of any Indian state, with Scheduled Tribes constituting 21.1 per cent of the state's population (roughly 1.5 crore people out of 7.26 crore as per the 2011 Census), spread across 46 recognised tribes, including three Particularly Vulnerable Tribal Groups.[6] This tribal concentration in the state's eastern and southern belts is the principal geographic driver of the region's elevated HbS prevalence, since the sickle mutation confers a survival advantage against Plasmodium falciparum malaria and has therefore persisted at high frequency in populations historically resident in malaria-endemic forested and hilly tracts.

Government-run screening and outreach in this eastern zone-organised on a hub-and-spoke model with a central sickle cell competency centre coordinating district-level "spoke" clinics across districts including Sidhi, Rewa, Seoni, Balaghat, Mandla, Jabalpur, Shahdol, Chhindwara, Narmadapuram, Raisen, and Betul-reflects the administrative recognition that this corridor requires concentrated diagnostic, counselling, and transfusion-support infrastructure.[8]

SINGRAULI DISTRICT: DEMOGRAPHIC PROFILE

Singrauli district, located in the north-eastern corner of Madhya Pradesh (Rewa division), was carved out as a separate district in 2008 and is often referred to as the "Energy Capital of India" owing to its coal and thermal-power industry. According to the 2011 Census of India:[5,6]

Total population was 11,78,273. The 6,13,637 were males and 5,64,636 were females. Decadal growth rate (2001-2011) was 28.03%. Sex ratio-916 females per 1,000 males. Population density-208 persons/km² over an area of 5,675 km². Urban-rural split approximately 19% urban and 81% rural. Literacy rate was 62.36% (male were ~76% and female ~52-53%). Scheduled Caste population was 12.79% and Scheduled Tribe population was 32.59%. Child population (0-6 years) was about 2,09,792 (roughly 18% of the total).

Note on population figures: 2011 remains the last official decennial Census of India; the 2021 Census has been postponed nationally and, as of 2026, has still not been conducted, so no official government population count or projection exists for Singrauli at the district level beyond 2011. Applying the district's own 2001-2011 decadal growth rate (28.03%), and consistent with independent demographic-estimation sources, the district's population by the mid-2020s can be roughly projected in the range of 14-15.5 lakh (1.4-1.55 million), though such figures are unofficial extrapolations and should be treated as indicative only, not as verified counts.[7] All percentage-based figures in this article (ST/SC share, sex ratio, literacy, etc.) are drawn from the 2011 Census and are assumed to remain broadly representative of the district's current demographic composition, since large shifts in caste/tribe proportion or sex ratio over a single intercensal period are uncommon.

Singrauli's tribal population is dominated by the Gond community (about half of all tribal residents) followed by the Kol community (about 16%), with smaller numbers of Baiga, Panika, and other groups; Hindi and Bagheli are the principal languages spoken. The district's administrative headquarters, Waidhan, and the industrial township of Singrauli city together form a largely rural, mining- and power-sector-dependent population with a high tribal and scheduled-caste share and comparatively lower female literacy-a demographic profile that closely parallels the caste/tribe pattern identified as high-risk for sickle haemoglobin inheritance in the wider Central Indian literature.

Given that nearly one in three residents of Singrauli district belongs to a Scheduled Tribe, and that Gond and Kol communities elsewhere in Madhya Pradesh have been repeatedly documented to carry high HbS frequencies, Singrauli falls squarely within the eastern Madhya Pradesh high-prevalence corridor for sickle cell trait and disease. Local point-of-care screening conducted through district hospital and community camps in Singrauli (HPLC-based testing of antenatal, school, and outpatient cohorts) has, in the author's institutional experience, shown a substantial combined positivity for sickle trait and disease among tested individuals, consistent with the district's tribal demographic profile and with rates reported from other high-prevalence districts of the eastern sickle cell belt.[9] Because Singrauli's dedicated diagnostic and genetic-counselling infrastructure is relatively recent, population-representative published prevalence figures specific to the district remain limited, and continued systematic HPLC-

based screening-of antenatal women, newborns, and school-age tribal children-is needed to establish a robust, publication-quality local prevalence estimate.

CLINICAL PROFILE: SCA VERSUS SBT

Detailed clinical data from the Central Indian sickle cell registry in Jabalpur, comparing 404 genetically confirmed SCA HbSS patients with 92 SBT patients, provide the most complete clinical picture available for the region and are broadly representative of the phenotype seen across the eastern Madhya Pradesh belt, including Singrauli.[2]

Demographics

The overall male-to-female ratio among registered patients was 2.1:1, attributed at least partly to preferential health-seeking behaviour for male children rather than any sex-linked component of the disease. Nearly one-third of patients (30.2%) were aged 5-10 years at registration, and about 44% of SCA patients (versus 36% of SBT patients) had shown their first disease symptoms before the age of 3.[2]

Common symptoms

Pallor (severe anaemia) was seen in over 95% of both SCA and SBT patients, followed by icterus (jaundice, ~86%), joint pain (~82%), fever (~78%), and fatigue (~77-84%). Bony pain affected roughly 61-64% of patients, hepatomegaly around 41%, and abdominal pain about 40-50%.[2]

Splenic involvement

Splenomegaly was the single most common objective clinical finding, present in 71.4% of all patients overall, and was significantly more frequent in SBT patients (82.6%) than in SCA patients (68.8%). Surgical splenectomy was required in roughly 2.2% of SBT patients compared with about 1% of SCA patients.[2]

Transfusion burden

Around 63-64% of patients required at least one blood transfusion during their clinical course, and about 16% of both groups required three or more transfusions, reflecting a substantial chronic care burden on district-level blood transfusion services.[2]

Distinctive complications

Dactylitis (hand-foot syndrome) was more common in young SCA children (4.2% in the 0-5 year age group) than in SBT children (1.0%), while avascular necrosis of the femoral head was more frequent in SBT individuals (2.2%) than SCA individuals (0.5%). The Jabalpur registry also documented the first recorded case of priapism in the Central Indian sickle cell population, underscoring how regional case series continue to expand the recognised phenotypic spectrum of SCD in India.[2]

THE PROTECTIVE ROLE OF FETAL HAEMOGLOBIN

A recurring and clinically important theme in Central Indian sickle cell research are the modulating effect of fetal haemoglobin (HbF). Because the sickle mutation in Indian populations is generally linked to the Arab-Indian beta-globin haplotype-associated with comparatively higher baseline HbF levels than the haplotypes common in Africa-the disease in Indian, and particularly tribal, patients tends to run a somewhat milder course than in populations of African descent, with fewer painful crises, infections, and hospitalisations.[1,2]

High prevalence of co-inherited alpha-thalassaemia among many tribal groups is thought to contribute further to this relatively attenuated phenotype. In the Jabalpur cohort, adult SBT males showed markedly higher mean HbF (16.5±7.1%) than SCA males (13.3±5.6%), and rising HbF levels were statistically associated with a linear reduction in bony pain, abdominal pain, chest pain, and fatigue among SCA patients, and with reduced transfusion requirement among SBT patients.[2]

This genotype–phenotype relationship has direct clinical relevance for risk-stratifying patients at district-level sickle cell clinics across the eastern belt, including Singrauli.

SCREENING, DIAGNOSIS, AND NEWBORN SCREENING INITIATIVES

Diagnosis of SCD in Madhya Pradesh has historically relied on the sickling/solubility test as a low-cost first-line screen, followed by confirmatory haemoglobin electrophoresis or high-performance liquid chromatography (HPLC). Point of care testing by sickle cell card test is now most commonly used method for screening in camps.

HPLC has now become the preferred confirmatory method in most state-run camps and district hospital laboratories, including in Singrauli, because it simultaneously quantifies HbS, HbF, and HbA2, allowing SCA to be distinguished from SBT and simple trait.

Newborn screening for sickle cell disorders in India is a relatively recent development, having been initiated over the last decade in parts of Gujarat, Maharashtra, Chhattisgarh, Odisha, and, more recently, Madhya Pradesh, where a newborn screening programme has been established in Jabalpur to track birth cohorts and enable early prophylactic care.[3]

Extension of similar systematic antenatal and newborn screening to eastern districts such as Singrauli, Sidhi, and Shahdol-where tribal birth rates and carrier frequency are

both high-represents a key unmet public health need, since early identification of HbSS and HbS-beta thalassaemia infants allows penicillin prophylaxis, vaccination, and family counselling to begin before the onset of life-threatening complications such as splenic sequestration or invasive infection.

State-level programmes have also established a hub-and-spoke model of care, in which a central "Centre of Competency" provides confirmatory genetic diagnosis, transfusion therapy, hydroxyurea-based medical management, and counselling, while district and block-level "spoke" facilities-such as the district hospital laboratory in Waidhan, Singrauli-carry out primary screening, registration, and routine follow-up, referring complicated cases upward.[8]

This decentralised model is intended to bring diagnosis and basic supportive care closer to the tribal-majority eastern districts where patients would otherwise face long travel distances to reach tertiary centres.

PUBLIC HEALTH IMPLICATIONS FOR SINGRAULI AND THE EASTERN BELT

High pre-test probability in tribal and endogamous communities

With Scheduled Tribes comprising roughly a third of Singrauli's population-dominated by Gond and Kol communities known elsewhere in the state to carry high HbS frequencies-universal or near-universal antenatal and school-based screening is justified on epidemiological grounds alone.

Premarital and antenatal counselling

Given the endogamous marriage patterns documented among affected scheduled caste and tribal communities in Central India, premarital carrier screening and counselling remain among the most cost-effective tools available to reduce the annual birth incidence of HbSS and HbS-beta thalassaemia children.

Chronic transfusion and blood-bank capacity

With roughly two-thirds of registered SCD patients in Central India requiring at least one transfusion, district blood-transfusion services in high-prevalence eastern districts need adequate voluntary donor pools and safe-transfusion (NAT/serology) capacity.

Early clinical suspicion

Because a large proportion of patients show first symptoms before age 3, and because splenomegaly is the dominant physical sign, primary health workers and paediatricians across the eastern belt should maintain a low threshold for HPLC referral in tribal children presenting with recurrent pallor, jaundice, fever, or abdominal/joint pain.

Local data generation

Publication-quality, population-representative prevalence data specific to Singrauli and neighbouring eastern districts (Sidhi, Shahdol, Anuppur) remain comparatively sparse relative to Jabalpur and Bhopal; systematic reporting of district hospital and camp-based HPLC screening outcomes from these districts would meaningfully strengthen the state's epidemiological map of the disease.

DISTRICT HOSPITAL, SINGRAULI: INSTITUTIONAL HPLC SCREENING DATA (2022–2025)

To supplement the state- and region-level literature reviewed above with local, district-level evidence, four years of institutional screening records from the Department of Pathology, District Hospital, Singrauli (Waidhan) are presented below.[9] Sickle cell testing at DH Singrauli during this period was performed using the solubility test as an initial screen, with HPLC used for confirmation and quantification of HbS, HbF, and HbA2, permitting differentiation of SCD (HbSS) from sickle trait/carrier (HbAS) status.

Table 1: Year-wise sickle cell screening outcomes, District Hospital, Singrauli (2022–2025).

Year	Screening total (sickle test)	SCD	Sickle trait/ carrier	Total positive
2022	767	50	65	115
2023	830	62	63	125
2024	1226	82	102	184
2025	1213	71	111	182
Total	4036	265	341	606

Across the four-year period, 4,036 individuals were tested, of whom 606 (15.0%) screened positive for sickle haemoglobin-265 (6.6% of all tested; 43.7% of all positives) with SCD and 341 (8.5% of all tested; 56.3% of all positives) with sickle trait/carrier status.[9] Year-on-year positivity remained remarkably stable, ranging narrowly between approximately 15.0% and 15.1% in each of the four years, despite a substantial rise in the absolute number of samples tested (from 767 in 2022 to a peak of 1,226 in 2024).

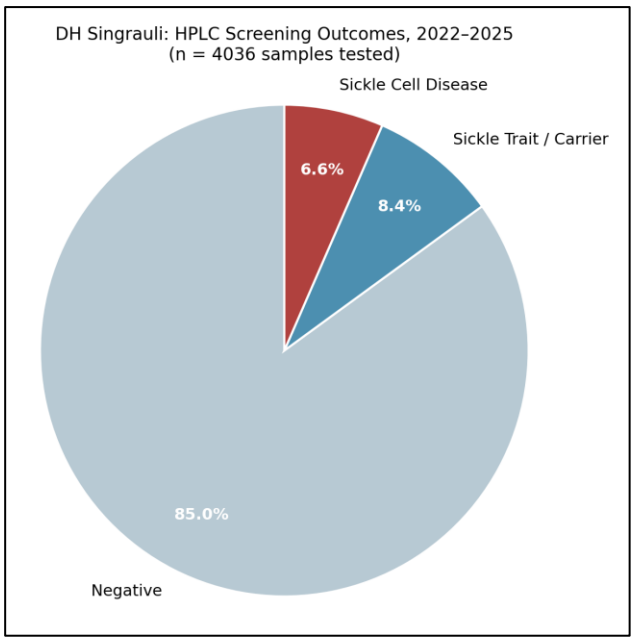

Figure 1: Composition of the DH Singrauli screened cohort, 2022-2025, (n=4,036).

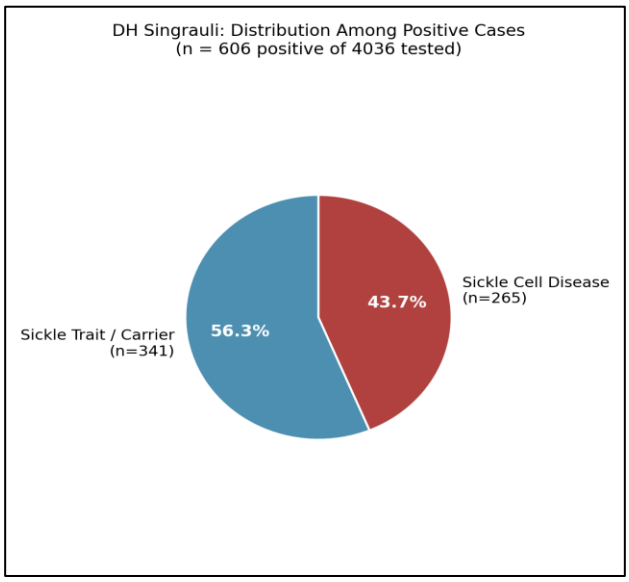

Figure 2: Distribution of SCD versus trait/carrier status among the 606 positive results, DH Singrauli, 2022-2025.

IMPORTANT CAVEAT: THIS INSTITUTIONAL POSITIVITY RATE IS NOT A POPULATION PREVALENCE ESTIMATE

The observed 14-17% overall positivity rate at DH Singrauli is substantially higher than the population-level HbS carrier frequency reported for tribal Central India in the published literature, and this figure should not be read as a representative estimate of sickle haemoglobin prevalence in the general population of Singrauli district.[1] This gap is explained by the case-mix of the hospital laboratory rather than by any true excess of sickle haemoglobin in the district as a whole, for several reasons:

Anaemia-clinic referral bias

The great majority of samples were drawn from patients already presenting with anaemia or clinical features suggestive of a haemoglobinopathy, rather than from an unselected, representative cross-section of the general population. This selects strongly for a higher pre-test probability of a positive result.

Family/contact testing

A substantial proportion of the samples tested represent first-and second-degree relatives of patients already known to have SCD or trait, tested specifically because of that family history. Because sickle haemoglobin is inherited, cascade testing of relatives of an index case yields a far higher positivity rate than testing an unrelated, random sample of the population.

Absence of a denominator representative of the district population

The 4,036 individuals tested over four years represent a small, non-random fraction of Singrauli's estimated population of roughly 14-15.5 lakh, and were not sampled using a population-based survey design (e.g. stratified random sampling by block, tribe, or age).

For these reasons, the true community-level prevalence of sickle cell trait and disease among the general population of Singrauli district is expected to be lower than the 14-17% institutional positivity rate reported here, and is likely to lie closer to the tribal carrier-frequency range (approximately 10-33%, with substantial inter-community variation) reported elsewhere in the eastern Madhya Pradesh sickle cell belt.[1,4] A dedicated, population-based screening survey-stratified by block, community, and age group, and independent of anaemia-clinic or family-contact referral-would be required to generate a publication-quality, unbiased prevalence estimate for the district, and remains a priority for the district hemoglobinopathy and rare disease programme.

CONCLUSION

Madhya Pradesh carries the largest absolute burden of sickle cell trait and disease of any Indian state, concentrated in a well-defined belt of 27 districts where carrier frequency reaches as high as a third of the tested population. The eastern flank of this belt-encompassing Singrauli and its neighbouring tribal-majority districts-shares the demographic drivers (high Scheduled Tribe and Scheduled Caste proportion, rural residence, endogamous marriage practice) that sustain high HbS frequency elsewhere in the state, and its patients can be expected to show the same clinical spectrum documented

in the larger Central Indian case series: early symptom onset, near-universal pallor and splenomegaly, substantial transfusion dependence, and a disease course modulated significantly by fetal haemoglobin level. Four years of institutional HPLC screening data from DH Singrauli, while not a population-representative prevalence estimate given their anaemia-clinic and family-contact case-mix, confirm a consistent and clinically significant burden of sickle haemoglobin disorders presenting to district-level care each year. Strengthening HPLC-based antenatal and newborn screening, premarital counselling, and district-level comprehensive care infrastructure in Singrauli and the wider eastern Madhya Pradesh belt-alongside dedicated population-based prevalence survey-remains central to reducing the future birth incidence and clinical morbidity of SCD in this high-risk region.

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