IJPHS:
International Journal of Psychology and Health Science
GREENATION PUBLISHER
+62 812 1046 7572 http://greenpub.org greenation.info@gmail.com
DOI: https://doi.org/10.38035/ijphs.v4i4
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Received: 28 September 2026 | **Revised:** 06 October 2026 | **Accepted:** 11 October 2026

Hearing Screening in High-Risk Neonates in NHCU of Dr. Hasan Sadikin Hospital Bandung

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Abstract: Neonatal hearing loss may remain unnoticed during early life and can interfere with speech, language, cognitive, emotional, and social development. This study described otoacoustic emission findings and hearing-loss risk factors among high-risk neonates treated at Dr. Hasan Sadikin General Hospital, Bandung. A retrospective descriptive study used medical-record data from 150 infants aged 0–12 months who underwent otoacoustic emission screening during 2024–2025. Consecutive sampling included infants with at least one documented risk factor and without outer- or middle-ear abnormalities that could interfere with testing. Among 150 high-risk infants, 131 passed OAE screening and 19 received refer outcomes during initial evaluation. Refer outcomes were proportionally more frequent among preterm and low-birth-weight infants than among their comparison groups. Two of three infants with a history of asphyxia were referred, although this subgroup was small. Most high-risk infants passed otoacoustic emission screening, but refer results remained evident in clinically vulnerable groups. Routine early screening, timely rescreening, and confirmatory auditory assessment are needed to support earlier diagnosis and intervention for infants at risk of permanent hearing loss and developmental consequences.

Keywords: Asphyxia, LBW, Neonates, OAE, Prematurity.

INTRODUCTION

Hearing loss in neonates is a clinically important problem because auditory input contributes directly to the development of speech, language, cognition, emotional regulation, and social communication from the beginning of life. Hearing impairment may remain unnoticed during infancy because it does not necessarily produce visible physical signs. Its consequences may become apparent only when a child shows limited responses to sound, delayed speech, or difficulty developing age-appropriate communication. This makes early detection an essential component of neonatal care, particularly for infants with documented risk factors. Neonatal hearing loss may be associated with hereditary and genetic factors, congenital conditions, perinatal complications, or disorders acquired after birth. Infants

requiring special or intensive neonatal care are exposed to more complex clinical conditions than healthy newborns and therefore require particular attention to auditory function (Al-Ani, 2023; Choe et al., 2023).

The burden of childhood hearing loss extends beyond reduced auditory sensitivity because delayed identification may affect multiple developmental domains. The World Health Organization (2021) identifies ear and hearing care as an important component of health throughout the life course and emphasizes that many consequences of childhood hearing loss can be prevented or reduced through timely detection and intervention. Early life is a sensitive period during which auditory stimulation supports maturation of the auditory pathway and language acquisition. Failure to identify hearing dysfunction during this period may reduce opportunities for the child to receive meaningful auditory stimulation when neurodevelopmental plasticity is high. Indonesian evidence likewise indicates that the age at which early intervention begins and the implementation of auditory-verbal therapy are associated with language development in children with speech delay and sensorineural hearing loss, demonstrating that screening is valuable primarily because it can accelerate access to diagnosis and habilitation (Purwanti et al., 2023).

In Indonesia, congenital sensorineural hearing loss has received formal attention through national clinical guidance emphasizing early identification, diagnostic evaluation, and intervention according to the child's clinical condition (Kementerian Kesehatan Republik Indonesia, 2022). This framework is consistent with the broader principles of early hearing detection and intervention, which link screening in early infancy with prompt diagnostic confirmation and timely intervention. The Joint Committee on Infant Hearing (2019) recommends an integrated pathway from screening to diagnosis and intervention so that children with permanent hearing loss can enter appropriate services without unnecessary delay. Newborn hearing screening programs can reduce the age of identification and facilitate earlier access to rehabilitation, although coverage, data systems, and service quality remain unequal across countries (Neumann et al., 2022).

One of the principal modalities used for newborn hearing screening is *otoacoustic emission* (OAE). OAE measures acoustic responses generated by the cochlea and primarily reflects the function of outer hair cells. The test is objective, relatively rapid, and non-invasive, which makes it suitable for infants who cannot provide reliable behavioral responses. A *pass* result indicates that the expected cochlear response is detected according to the screening criteria, whereas a *refer* result indicates that the infant requires repeat screening or additional assessment and should not automatically be labeled as having permanent hearing loss. When a screening result remains abnormal, objective assessment such as *auditory brainstem response* (ABR) can provide further information about auditory pathway function. Indonesian literature describes OAE and ABR as complementary objective tools that can be arranged in sequential newborn screening protocols according to available resources and referral systems (Hamam & Purnami, 2020).

Newborn hearing screening can be organized as *universal newborn hearing screening* (UNHS), in which all newborns are screened, or as *targeted newborn hearing screening* (TNHS), in which screening is prioritized for infants with recognized risk factors. A targeted strategy is often used when equipment, trained personnel, funding, or follow-up systems are limited. Nevertheless, risk-based screening can miss infants whose permanent hearing loss occurs without a documented risk factor. Allisha et al. (2022) found that some children with sensorineural hearing loss in Jatinangor had no identifiable risk factor, supporting the principle that early hearing detection should ultimately extend beyond only high-risk groups. Screening of high-risk neonates therefore remains essential, but it should be understood as one component of a broader goal to expand equitable early hearing detection for all infants.

Risk factors frequently discussed in neonatal hearing care include prematurity, low birth weight (LBW), perinatal asphyxia, severe hyperbilirubinemia, ototoxic medication

exposure, congenital infection, mechanical ventilation, craniofacial anomalies, and other conditions associated with neonatal intensive care. Prematurity and LBW commonly occur together because infants born before full maturation may also have lower birth weights, immature organ systems, and a greater need for complex medical support. The auditory system of a preterm infant is still undergoing maturation, and hypoxia, systemic illness, pharmacologic exposure, and other comorbidities may affect cochlear or neural auditory function. At Dr. Kariadi Central General Hospital, Liemiyah et al. (2022) used OAE to characterize newborn screening outcomes and identified LBW among the commonly recorded risk factors in the screened population.

Previous Indonesian studies provide important but heterogeneous evidence. Purnami et al. (2018) described infants and young children with sensorineural hearing loss at Dr. Soetomo Hospital and found that many children were identified when speech and language delay had already become clinically relevant, while a clear risk factor was not always available. Wijana et al. (2020) identified hearing impairment among children younger than five years in Jatinangor using behavioral assessment, OAE, and tympanometry, demonstrating the relevance of early detection beyond tertiary hospitals. Studies of individual risk factors have also produced differing results, indicating that the importance of prematurity, LBW, asphyxia, and other perinatal conditions may vary according to population characteristics, study design, diagnostic definition, and clinical setting. Local institutional data are therefore necessary rather than assuming that findings from one center can be applied directly to another.

Dr. Hasan Sadikin General Hospital in Bandung is a major referral hospital that receives neonates with diverse and often complex clinical conditions from West Java. Comprehensive local data describing OAE findings among high-risk infants from the neonatal high-care setting who were referred for otorhinolaryngology evaluation during 2024-2025 remain limited. Such information is relevant because the distribution of risk factors, referral patterns, timing of screening, and proportion of *refer* results may differ among facilities. Descriptive data from a referral center can support service evaluation, identify groups requiring closer audiological surveillance, and provide a basis for improving repeat-screening and diagnostic referral pathways. Accordingly, this study aimed to evaluate the characteristics of OAE findings and documented hearing-loss risk factors among high-risk infants examined at Dr. Hasan Sadikin General Hospital, Bandung.

METHODS

This study employed a retrospective descriptive design using secondary data from the medical records of infants who received neonatal care and subsequently underwent hearing evaluation at the Department of Otorhinolaryngology-Head and Neck Surgery outpatient service of Dr. Hasan Sadikin General Hospital, Bandung, during the 2024-2025 period. The accessible population consisted of infants with documented risk factors for hearing loss who underwent OAE screening. A total of 150 infants fulfilled the study criteria. A *consecutive sampling* approach was applied in which all eligible subjects encountered sequentially during the study period were included in the analyzed dataset.

The inclusion criteria were infants aged 0-12 months with at least one documented hearing-loss risk factor, including prematurity, LBW, or perinatal asphyxia, and without structural abnormalities of the outer or middle ear that could interfere with OAE measurement. Infants with congenital or acquired disorders of the outer or middle ear that could affect the accuracy of OAE testing were excluded. Variables extracted from the records included sex, gestational age, birth weight, history of asphyxia, and OAE screening outcome.

Otoacoustic emission testing was used as an objective screening measure of cochlear function. For OAE screening, a *pass* result was defined by an amplitude response of at least 6 dB SPL at a minimum of three tested frequencies, namely 2, 3, and 4 kHz. A *refer* result was

assigned when OAE waveforms were not detected according to the stated criteria. In this study, *refer* was treated as a screening outcome requiring follow-up rather than a definitive diagnosis of hearing loss. This distinction is clinically important because OAE results may be influenced by conditions present at the time of testing, while diagnostic assessment, including ABR when indicated, is required to establish hearing status.

The data were tabulated and analyzed descriptively using Microsoft Excel. Frequencies and proportions were used to summarize subject characteristics and OAE screening outcomes. Findings were presented in a table of subject characteristics and a table showing OAE outcomes according to the recorded risk-factor categories. Percentages were calculated from the observed frequencies using the appropriate total or subgroup denominator. Because the study objective was descriptive, no hypothesis testing or inferential modeling was performed. Interpretation focused on the distribution of clinical characteristics and OAE screening outcomes among the included infants.

The descriptive analysis compared *pass* and *refer* patterns within each characteristic category. Sex-specific proportions were calculated using the number of male and female infants as the respective denominators. Gestational-age proportions were calculated separately for full-term and preterm infants, while birth-weight proportions were calculated for normal-birth-weight and LBW groups. For asphyxia, proportions were calculated separately among infants with and without a documented history of asphyxia. Because the asphyxia subgroup was very small, its findings were interpreted cautiously and were not used to infer causal risk.

RESULTS AND DISCUSSION

Result

Subject Characteristics

The characteristics of infants who fulfilled the study criteria are summarized in Table 1. The table presents the distribution of sex, gestational age, birth weight, and history of asphyxia. Percentages were calculated from the observed frequencies relative to the total sample. No inferential statistical test was performed because the study was descriptive.

Table 1. General Characteristics and Hearing-Loss Risk Factors

Characteristic	Category	n	%
Gender	Male	82	54.7
	Female	68	45.3
Gestational age	Full-term	111	74.0
	Preterm	39	26.0
Birth weight	Normal	101	67.3
	Low birth weight	49	32.7
Asphyxia	Yes	3	2.0
	No	147	98.0

Note. Percentages are based on the total sample (n = 150).

Distribution of OAE Outcomes by Risk-Factor Category

The distribution of OAE outcomes across the recorded characteristics is presented in Table 2. Descriptively, *refer* outcomes were more prominent among preterm and LBW infants than among their respective comparison groups. The asphyxia subgroup also showed a pattern that warrants clinical attention, although the subgroup was very small. Because the study was not designed to test statistical associations, differences shown in Table 2 are not interpreted as evidence of causality.

Table 2. OAE Screening Outcomes by Subject Characteristics

Characteristic	Category	Pass, n (%)	Refer, n (%)	Total
Gender	Male	72 (87.8)	10 (12.2)	82
	Female	59 (86.8)	9 (13.2)	68

Gestational age	Full-term	102 (91.9)	9 (8.1)	111
	Preterm	29 (74.4)	10 (25.6)	39
Birth weight	Normal	93 (92.1)	8 (7.9)	101
	Low birth weight	38 (77.6)	11 (22.4)	49
Asphyxia	Yes	1 (33.3)	2 (66.7)	3
	No	130 (88.4)	17 (11.6)	147
Overall	All infants	131 (87.3)	19 (12.7)	150

Note. Percentages are within-category proportions. A refer result is a screening outcome and does not constitute a definitive diagnosis of hearing loss.

Discussion

Overall Pattern of OAE Screening Outcomes

The main finding of this study is that most high-risk infants obtained a *pass* result on OAE screening, while a smaller proportion required follow-up because they received a *refer* result. This pattern should be understood as the distribution of screening outcomes in a referral population rather than as the prevalence of permanent hearing loss. OAE is highly useful for initial screening because it provides objective information about cochlear function, but a *refer* result can occur under several conditions and requires repeat or confirmatory assessment. The clinical value of the present findings therefore lies primarily in identifying infants who need a more structured pathway after the first screening rather than in assigning a definitive auditory diagnosis.

Male infants constituted the larger sex group in the study, but the distribution of *pass* and *refer* outcomes appeared broadly similar between male and female infants. Regina et al. (2017) also reported a slightly higher proportion of males in a population of high-risk infants undergoing audiological screening. Sex distribution alone, however, should not be interpreted as a determinant of neonatal hearing loss. The difference in the number of male and female subjects may simply reflect the characteristics of infants referred during the study period, while assessment of an independent association would require an analytical design and an adequate sample size.

The general screening pattern is comparable with experience from another Indonesian referral hospital, where most screened newborns obtained a *pass* outcome and a smaller group required further assessment. Liemiyah et al. (2022) reported predominantly *pass* OAE results among newborns at Dr. Kariadi Central General Hospital and emphasized the importance of considering accompanying risk factors. Similarity in the overall pattern supports the practical use of OAE in referral hospitals, although the exact *refer* proportion may vary according to patient characteristics, timing of testing, clinical stability, equipment, testing protocol, and local follow-up procedures.

A *refer* result should not be equated directly with sensorineural hearing loss because OAE is a screening rather than a definitive diagnostic test. Repeat screening after the infant is clinically stable, assessment of the outer and middle ear, and ABR may be necessary to establish hearing status. Hamam and Purnami (2020) described OAE and ABR as complementary objective examinations in newborn hearing-screening pathways. A sequential approach helps avoid two important problems: delayed diagnosis in infants with genuine permanent hearing loss and premature labeling of infants whose initial *refer* result may be transient or related to test conditions.

The service context is also important. Infants treated in neonatal units have more heterogeneous medical conditions than healthy newborns, and prematurity, low birth weight, perinatal complications, medication exposure, and other comorbidities may coexist. Screening results therefore need to be interpreted together with the clinical history rather than in isolation. Neumann et al. (2022) showed that the effectiveness of newborn hearing screening depends not only on whether a test is available, but also on coverage, data capture, follow-up, and access to subsequent services. The *refer* group in this study should

consequently be viewed as a signal for strengthening the follow-up system rather than merely as a screening statistic.

Prematurity and Low Birth Weight

Preterm infants in this study showed a greater proportion of *refer* outcomes than full-term infants. This pattern has biological plausibility because maturation of the cochlea, brainstem, and auditory pathways continues through prenatal and early postnatal life. Birth before full maturation may occur while these processes are incomplete, and preterm infants are also more likely to experience medical conditions requiring intensive treatment. Prematurity may therefore represent both developmental immaturity of the auditory system and a marker for additional exposures that can influence auditory function.

International evidence supports close attention to prematurity. Wroblewska-Seniuk et al. (2017) reported that hearing impairment occurred more frequently in infants born at lower gestational ages than in term controls. Frezza et al. (2023) likewise demonstrated that very-low-birth-weight infants carry multiple clinical factors associated with sensorineural hearing loss, including the complexity of neonatal care and exposure to ototoxic therapy. Although populations, diagnostic definitions, and testing schedules differ among studies, these findings support more intensive audiological surveillance in infants born before full gestational maturity.

LBW was another prominent risk-factor category in the present dataset, and *refer* outcomes were proportionally more common in the LBW group than in infants with normal birth weight. Low birth weight may reflect prematurity, impaired fetal growth, or other perinatal problems that can also affect sensory development. Nisotakis et al. (2016) reported an association between LBW and hearing impairment among neonates treated in a neonatal intensive care setting. In an Indonesian case-control study, Rianto et al. (2017) identified LBW as one of the noninfectious factors associated with pediatric sensorineural hearing loss, providing additional support for retaining birth weight as an important risk marker in targeted hearing screening.

National evidence also supports the clinical relevance of gestational age and birth weight in auditory surveillance. Handayani et al. (2021) examined prematurity and LBW in relation to the degree of hearing impairment in children and placed both variables among important elements of the perinatal history. Such information is particularly useful in referral hospitals because birth data are generally available early and can be used to determine the need for screening and continued surveillance before speech delay or other developmental concerns become apparent.

Nevertheless, associations between prematurity, LBW, and hearing impairment are not uniform across all studies. Gultom and Rambe (2021) did not identify statistically significant relationships between a history of prematurity or LBW and hearing impairment in the pediatric population they studied. Susyanto and Widuri (2015) similarly reported no statistically significant relationship for prematurity in their study population. These findings are not necessarily contradictory because study design, sample size, subject characteristics, definitions of hearing impairment, timing of assessment, and coexisting risk factors may differ substantially. The implication for the present study is that its descriptive pattern must not be elevated into a causal claim in the absence of inferential analysis and control of confounding variables.

Prematurity and LBW should also be considered as potentially overlapping risk indicators. Many preterm infants have low birth weight, but not every infant with LBW is preterm. Cross-tabulation of these two factors was not available, so the number of infants who had both characteristics simultaneously cannot be determined. This limitation matters because an individual infant may contribute more than one risk factor, while separate category summaries can create the impression that each factor operates independently. Future

studies should document combinations of risk factors so that cumulative clinical vulnerability can be assessed more accurately.

Perinatal Asphyxia and Other Clinical Risk Factors

The asphyxia subgroup showed a pattern that deserves attention because most infants in this very small group received a *refer* result. Biologically, perinatal asphyxia can cause hypoxia and metabolic disturbance that may affect cochlear hair cells or neural auditory pathways. Anggraeni et al. (2021) described neonatal asphyxia as a factor associated with sensorineural hearing loss in Indonesian children. Rianto et al. (2017) also identified asphyxia as one of the noninfectious factors associated with pediatric sensorineural hearing loss in their case-control analysis.

The number of infants with documented asphyxia in the present study was, however, very small. A high proportion of *refer* outcomes in such a small subgroup cannot be used to estimate the strength of association or the magnitude of risk in a broader population. A change in the outcome of a single infant would substantially alter the percentage. The appropriate interpretation is therefore that a history of asphyxia remains a clinically important reason for audiological vigilance and follow-up, while the present study is not capable of quantifying its statistical relationship with hearing impairment.

The range of neonatal hearing-loss risk factors is broader than the three variables evaluated in this study. Congenital infection, severe hyperbilirubinemia, craniofacial anomalies, family history, ototoxic medication exposure, prolonged mechanical ventilation, meningitis, genetic disorders, and other serious neonatal illnesses can contribute to auditory dysfunction. Muyassaroh and Rahmi (2022) showed that sensorineural hearing loss is an important manifestation among pediatric patients with congenital rubella syndrome. This evidence highlights the need for risk surveillance that extends beyond prematurity, LBW, and asphyxia, particularly in a tertiary referral hospital caring for clinically complex infants.

The limited set of clinical variables evaluated in this study reduces the ability to explain why an individual infant received a *refer* result. Several risk factors may coexist in an infant admitted for neonatal care, and each may contribute differently to cochlear or neural auditory function. Future data collection should include aminoglycoside or other ototoxic drug exposure, duration of neonatal hospitalization, mechanical ventilation, hyperbilirubinemia, sepsis, congenital infections, craniofacial abnormalities, and family history. A more complete dataset would allow investigators to move beyond simple distributions and examine which combinations of factors most frequently accompany abnormal screening outcomes.

Implications for Early Screening and Follow-up Systems

The present results reinforce the importance of early hearing screening in high-risk infants while also illustrating the limitation of a strategy based exclusively on known risk factors. Purnami et al. (2018) reported that the cause or recognized risk factor was unknown in a large proportion of infants and children with sensorineural hearing loss treated at a referral clinic. Allisha et al. (2022) likewise identified sensorineural hearing loss in children without documented risk factors. TNHS therefore remains useful where resources are limited, but the long-term direction of services should favor broader coverage so that infants without recognized risk factors are not systematically missed.

Community-based evidence from Jatinangor provides an additional perspective. Wijana et al. (2020) identified hearing impairment among children younger than five years through an assessment program that combined behavioral and objective hearing examinations, showing that early detection is relevant beyond tertiary-care settings. Stronger linkage among primary care, maternal and neonatal services, referral hospitals, and audiology centers may reduce loss to follow-up. At the hospital level, every *refer* result should be connected to a

defined repeat-screening or diagnostic appointment and to a data system that allows staff to determine whether the infant actually completes the next stage of evaluation.

Recent Indonesian evidence further supports more complete recording of infectious risk factors. Rianto et al. (2024) evaluated Toxoplasma, rubella, cytomegalovirus, and herpes virus infections among children with sensory hearing loss and found that the combination of rubella and cytomegalovirus was the most prominent risk pattern in their population. For Dr. Hasan Sadikin General Hospital, this suggests that a neonatal hearing-screening database should ideally contain not only prematurity, LBW, and asphyxia, but also congenital-infection history and related laboratory information when available. Structured data would make it possible to evaluate age at screening, repeat-screening outcome, ABR result, final diagnosis, time to intervention, and loss to follow-up.

Program success should not be evaluated only by the proportion of infants who *pass* an initial screening. Infants with a *refer* result require a clear follow-up process, while some high-risk infants who initially *pass* may still need surveillance because certain conditions are associated with delayed-onset or progressive hearing loss. JCIH (2019) emphasizes ongoing surveillance of auditory and communication development rather than relying on a single neonatal test. In practice, screening should therefore be integrated with parent education, monitoring of speech and language milestones, and rapid re-referral when developmental or auditory concerns emerge.

The ultimate purpose of screening is to shorten the interval between the presence of hearing impairment, its identification, and the beginning of appropriate intervention. Purwanti et al. (2023) showed that the age at early intervention was meaningfully related to language development among children with speech delay and sensorineural hearing loss. This provides a practical reason for active management of every persistent *refer* result. Delays in repeat screening, diagnostic confirmation, amplification, cochlear-implant evaluation when indicated, or habilitation can reduce opportunities for effective auditory stimulation during an important period of language development.

Overall, this study provides useful local information on OAE outcomes among high-risk infants at a major referral center in West Java. Its principal contribution is not proof of cause and effect but a description of groups requiring attention and of areas where the screening system can be strengthened. The pattern of more frequent *refer* outcomes among preterm and LBW infants, together with the notable but numerically unstable pattern in the small asphyxia subgroup, can support local clinical audit and future study design. Better data quality, consistent definitions, documentation of combined risk factors, and complete follow-up records would substantially improve the value of newborn hearing-screening data for clinical and institutional decision-making.

CONCLUSIONS AND RECOMMENDATIONS

This study shows that most high-risk infants undergoing OAE screening at Dr. Hasan Sadikin General Hospital, Bandung, obtained a *pass* result, while a smaller group obtained a *refer* result and therefore required further evaluation. Descriptively, *refer* outcomes were more common among preterm and LBW infants than among their respective comparison groups. The asphyxia subgroup also showed a high proportion of *refer* outcomes, but the number of infants in this subgroup was too small to support conclusions regarding the magnitude of risk. These findings confirm the practical value of OAE as an initial screening tool for high-risk neonates while emphasizing that a *refer* outcome must be followed by repeat screening and confirmatory audiological assessment before definitive hearing status is established.

The study has several limitations. Its retrospective descriptive design depends on the completeness and accuracy of medical records. Available risk-factor variables were limited to prematurity, LBW, and asphyxia, so other relevant conditions such as hyperbilirubinemia,

congenital infection, ototoxic medication exposure, mechanical ventilation, sepsis, craniofacial anomalies, and family history could not be analyzed. Cross-tabulation of combined risk factors, repeat OAE results, ABR findings, final diagnoses, and follow-up status were not available for analysis. In addition, the asphyxia subgroup was very small and no inferential analysis was performed. The study therefore cannot establish causal relationships or quantify the independent risk associated with each factor.

Future practice should maintain early hearing screening as a routine component of care for high-risk infants while developing a more structured follow-up system. Hospitals should document the timing of screening, repeat-screening results, ABR findings, final diagnosis, intervention, and loss to follow-up in an integrated database. Future studies should include larger samples, more comprehensive risk-factor variables, and multivariable analysis so that the contribution of individual factors can be evaluated after potential confounders are considered. Expansion toward a more universal screening approach should also be considered so that infants without documented risk factors have the same opportunity for early identification and timely intervention.

Acknowledgment

We express our sincere gratitude to the patients, resident colleagues, and our consultant doctors in the RSUP Dr. Hasan Sadikin ENT Department for all their support and contribution in this research.

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