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Assessing the Water Quality of Creek Systems at Caraga State University-Main Campus, Philippines, using Macroinvertebrate-based Biotic Indices

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A B S T R A C T

Macroinvertebrates are widely utilized for monitoring water bodies and assessing water quality. In this study, macroinvertebrates were sampled from different gradients (upstream, midstream, and downstream) of four creeks within the main campus of Caraga State University. The study utilized a modified kick-net method to evaluate their species diversity, composition, and richness. A total of 20 taxa of macroinvertebrates from seven orders and 16 families were collected and identified across the subsampling stations. Gastropoda was the most abundant order, making up 65.51% of the total, with representatives from five families. Despite this abundance, the Shannon Diversity Index indicated very low diversity across all creek systems. However, the Pollution Tolerance Index (PTI) and the Biological Monitoring Working Party (BMWP) scores consistently showed good water quality across all subsampling stations. These results align with the Family Biotic Index (FBI) score, which suggests excellent water quality with no apparent organic pollution throughout the creeks. This study highlights the value of family-level identification in biomonitoring programs at CSU and similar environments. This method is cost-effective and practical, particularly in contexts with limited systematic knowledge of macroinvertebrates.

Keywords: *Biological indicator, biomonitoring, BWMP, diversity index, tropical stream*

1 Introduction

Water pollution is a global issue that deteriorates water quality and restricts its usability for various purposes (Etemi et al. 2020). For water to be safe for drinking, agriculture, or recreational use, it must adhere to specific physicochemical and microbiological standards. Consequently, water quality assessments often involve examining various physicochemical, microbiological, and biological parameters essential for evaluating ecological and environmental health (Popovic et al. 2016; Atique & An 2018; Kebede et al. 2020). There is also a growing focus on monitoring freshwater ecosystems worldwide to enhance their ecological, recreational, and economic value (Zamora-Munoz & Alba-Tercedor, 1996; Tanaka et al. 2016; DEPC 2000; Kebede et al. 2020).

Unlike traditional physicochemical assessment methods, biological indicators offer a cumulative view of ecosystem health by reflecting the responses of aquatic communities to various stressors in their habitat (Kebede et al. 2020). Characteristics such as diversity, richness, and abundance of these communities are used to gauge pollution levels, complementing and enhancing physicochemical data (Arimoro et al. 2007; Edward & Ugwumba 2011; Flores & Zafaralla 2012).

The use of macroinvertebrates in the biological evaluation of water bodies includes several advantages: (1) benthic macroinvertebrates are common and present in the majority of aquatic habitats; (2) different groups have different environmental needs and tolerances to pollution; (3) they are the food source for many species of fish; (4) small order streams often do not support fish but do support macroinvertebrate communities; (5) due to their immobility, benthic invertebrates serve as indicators of the local environment; (6) their body size is ideal to be easily collected and identified (Etemi et al. 2020); and (7) sampling is easy and cost-effective.

Biomonitoring employs indicators or sentinel species to evaluate environmental health or pollution by combining diversity metrics with pollution tolerance information into a single index or score. Benthic macroinvertebrates are among the most reliable indicators for biotic indices (Etriieki & Kucukbasmaci 2024). Numerous studies on Philippine freshwater systems have utilized these organisms to assess stream and river conditions, often correlating macroinvertebrate data with water classifications based on physicochemical parameters (Magbanua et al. 2023). Commonly used biotic indicators in the Philippines include the Pollution Tolerance Index (PTI), Biological Monitoring Working Party (BMWP), and Family Biotic Index (FBI). However, studies may vary in their evaluations of stream conditions.

In the Caraga Region, no specific study has employed a biotic index to assess water quality through macroinvertebrate evaluation. The research by Paylangco et al. (2021) focused solely on the relationships between macroinvertebrates and water physicochemical parameters in ten littoral zone stations across four municipalities of Lake Mainit, Philippines. In this study, we aimed to fill this gap by using the biotic index to assess the health of the creek systems at Caraga State University (CSU) by examining macroinvertebrate communities. The study focused on determining macroinvertebrates' abundance, composition, and diversity and utilized macroinvertebrate-based indices to evaluate water quality. Although the composition of macroinvertebrate assemblages is affected by various factors, such as water quality, physical habitat structure, and flow regime, these elements were not included in the analysis due to time constraints during data collection.

2 Materials and Methods

Study area and establishment of sampling stations

This field study was undertaken between April 25–26, 2022, during the dry season when sites were accessible and hydrologically stable. The field sampling was carried out in four selected creek systems inside Caraga State University, province of Agusan del Norte, specifically in the areas of Harrison Bridge (S1), Eco-Park (S2), Carabao Center (S3) and Basag (S4), respectively (Figure 1). Caraga State University is surrounded by domestic activities, agricultural fields, and residential areas where the creeks become contaminated with wastewater, agricultural runoff, industrial discharges, solid waste, and other pollutants, the principal anthropogenic stressors on the streams.

The creek flow's upper section (Harrison Bridge) was connected to the Ampayon Public Market and probably disturbed by domestic activities. The Eco-Park was located in a forest area in CSU, where the stream appears stagnant due to the very shallow streambed. Carabao Center is near the agricultural pastures and rice fields, with abundant moist plant debris and fallen logs. Lastly, the Basag area is surrounded by rice fields and residential areas.

Four sampling stations (creeks) with three represented subsamples were determined: the upper stream, middle stream, and downstream. At each sampling station, a 100-m transect line parallel to the stream flow to the water body was established in an accessible area. Three sampling points that serve as subsamples were established by marking twenty meters with a twenty meter-interval in a 100-meter transect line.

Macroinvertebrate collection and identification

The collection of macroinvertebrates was done using the kick-net method. A modified kick-net measuring 0.5 m width with 500µm opening mesh size was used to collect the organisms. The collection used a standard three-minute kick/sweep method (Armitage et al. 1990) by disturbing the streambed in a kicking motion in the direction of the modified dip-net. Sampling was carried out from the downstream to the upstream direction. The collected samples were placed in labeled containers with water. A 0.5mm mesh sieve separated the organisms from stream sediments and other debris. The collected

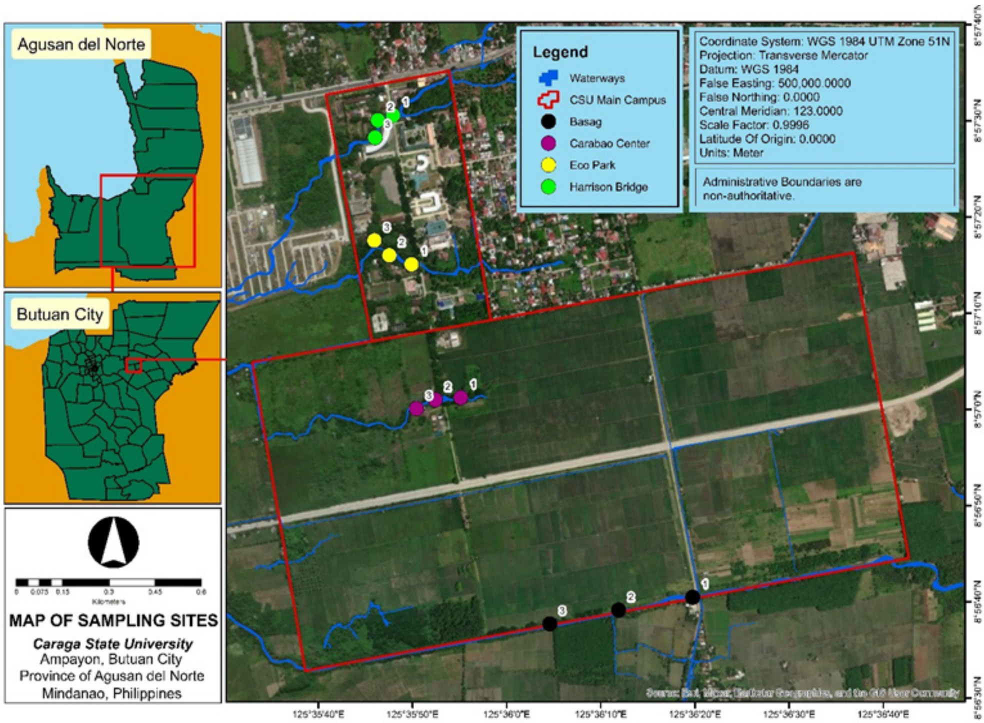

Figure 1. Map showing the sampling points for aquatic macroinvertebrate assessment across the four stream systems within Caraga State University-Main Campus

samples were sorted and stored in 95% ethanol in the laboratory. Using the principal manuals of Bouchard (2004) and Nesemann et al. (2011), identification was only at the family level. This study was limited to identifying and determining the composition, abundance, and richness of macroinvertebrates collected at the sampling sites during the sampling period. Several factors affect these variables, but the temporal distribution was not studied due to limited data-gathering time. Physicochemical parameters of water were also not included in this study.

Pollution Tolerance Index (PTI)

In this study, the Pollution Tolerance Index (PTI) was utilized to evaluate the condition of the creek systems at Caraga State University. This index involved analyzing the presence and abundance of macroinvertebrate species. Each identified taxa was categorized according to its pollution tolerance level (sensitive, somewhat tolerant, or tolerant), referencing regional or local ecological guides. Tolerance scores were assigned numerical values ranging from 1 to 3 for sensitive species, 4 to 7 for somewhat tolerant species, and 8 to 10 for tolerant species (Barbour et al. 1999).

Biological Monitoring Working Party Index (BMWP)

The Biological Monitoring Working Party Scoring System developed by Forio et al. (2017) was used to classify and score the identified macroinvertebrates. Each macroinvertebrate taxon is assigned a sensitivity score, with higher scores indicating greater sensitivity to environmental disturbances. The sensitivity scores of all observed taxa were accounted for at each site. A higher cumulative score signifies better ecological quality. The total was calculated and then divided by the number of taxa scored. The resulting value is the BMWP, which is shown in Table 1.

Family Biotic Index (FBI)

Hilsenhoff's (1977, 1988a, 1988b) Family Biotic Index was also used to assess water quality in the sampling stations. This index was calculated by multiplying the number in each family by the family-level pollution tolerance value/score, adding the results, and dividing by the total number of individuals in the sample. Table 2 describes the value obtained by the FBI.

Taxon richness, evenness, and diversity indices

The collected data were used to compute taxon richness(d'), evenness, Shannon- Wiener diversity index (H'), and Simpson's dominance index (S') (D). Shannon-Weiner was classified based on a modified scale (Table 3).

3 Results and Discussion

Abundance, composition, and diversity of macroinvertebrates

A total of 20 taxa, encompassing 1801 macroinvertebrates across seven orders and 16 families, were collected during the sampling period (Table 4). Among the sites, Carabao Center had the highest number of individuals, followed by Harrison Bridge, Eco-Park, and Basag area. Carabao Center had a greater number of individuals. Figure 2 illustrates the relative percentage composition of the major macroinvertebrate taxa in the four streams. Among the collected taxa, segmented worms (Oligochaeta), pebble snails (Hydrobiidae), and rock snails (Pleuroceridae) were frequently found in the Harrison Bridge, Eco-Park, and Carabao Center sites. Still, they were notably absent in the Basag area (Table 4).

The density and diversity of benthic groups identified in this study may be influenced by physicochemical properties altered by human activities (Dumbrava-Dumbrava and Petrovici, 2010). During the field assessment, sampling points in Eco-Park and Carabao Center, located upstream, exhibited cloudy water, domestic animals, and leaf litter. However, these factors might not significantly impact the overall health of the creek ecosystem. Conversely, a higher abundance of Hydrobiidae was observed at Harrison Bridge, Eco-Park, and

Table 1. Biological monitoring working party index scores and indication

Score	Indication
> 100	Very Good
71-100	Good
41-70	Poor
11-40	Poor
< 11	Bad

Source: Forio et al. (2017)

Table 2. Water quality based on the Family Biotic Index values from Hilsenhoff (1988b)

Family Biotic Index	Water quality	Degree of organic pollution
0.00–3.50	Excellent	No apparent organic pollution
3.51–4.50	Very good	Possible slight organic pollution
4.51–5.50	Good	Some organic pollution
5.51–6.50	Fair	Fairly significant organic pollution
6.51–7.50	Fairly poor	Significant organic pollution
7.51–8.50	Poor	Very significant organic pollution
8.51–10.0	Very poor	Severe organic pollution

Table 3. H’ diversity value and its qualitative equivalence

H’ value	Relative values
>3.5	Very high
3.0-3.49	High
2.5-2.99	Moderate
2.0-2.49	Low
<1.99	Very low

Source: Fernando (1998)

Table 4. List of macroinvertebrates collected in four creek systems and their corresponding taxa groupings based on their sensitivity to pollution and their respective family tolerance values

Order	Family	Common name	Number of individuals					Taxa groupings	FBI tolerance values for the Family biotic index	BMWP tolerance values
			S1	S2	S3	S4	Total			
Annelida	Hirudinea	Leech	9	82	*	*	91	3	1,2,38	63
	Oligochaeta	Segmented worms/ aquatic earthworm	14	5	145	*	164	3	1,2,310	61
Araneae	Dictynidae	Diving bell spider	*	*	*	2	2	1	14	-
Collembola	Poduroidea	Water springtails	2	*	1	*	3	3	49	-
Diptera	Ceratopogonidae	Non-biting midge	204	4	*	*	208	2	47	54
	Ceratopogonidae	Biting midge	*	*	2	*	2	2	47	54
	Tipulidae	Crane flies	*	*	2	*	2	2	44	62
Gastropoda	Hydrobiidae	Pebble snail	225	133	414	*	772	3	47	75
	Pleuroceridae	Rock snail	121	67	119	*	307	3	42	63
	Valvatidae	Round-lipped snail	*	1	1	*	2	3	42	63
	Sphaeriidae	Pea clam	*	*	98	*	98	3	17	74
	Ancylidae	Limpet	*	*	1	*	1	3	12	74
Hemiptera	Veliidae	Water strider	*	3	*	131	134	2	14	65
	Veliidae	Broad-shouldered water strider	*	*	5	*	5	2	14	65
	Veliidae	True bugs	*	*	1	*	1	2	15	65
Odonata	Gomphidae	Clubtail dragonfly	*	2	*	*	2	2	10	74
	Coenagrionidae	*Narrow-wing damselfly*	1	1	*	*	2	2	13	64
	Calopterygidae	Broad-wing damselfly	1	2	*	*	3	2	13	64
	Macromiidae	Dragonfly nymph	*	*	1	*	1	2	14	66
	Macromiidae	Dragonfly	*	*	*	1	1	2	14	66
		TOTAL	577	300	790	134	1801			

Note: (*) not found; (-) no available data; [1]Barbour at al. (1999); [2]Lenat (1993); [3]Resh et al (1995); [4]USEPA (2019); [5]Chessman (2003a); [6]Le et al. (2002); [7]Ruiz-Picos et al. (2017)

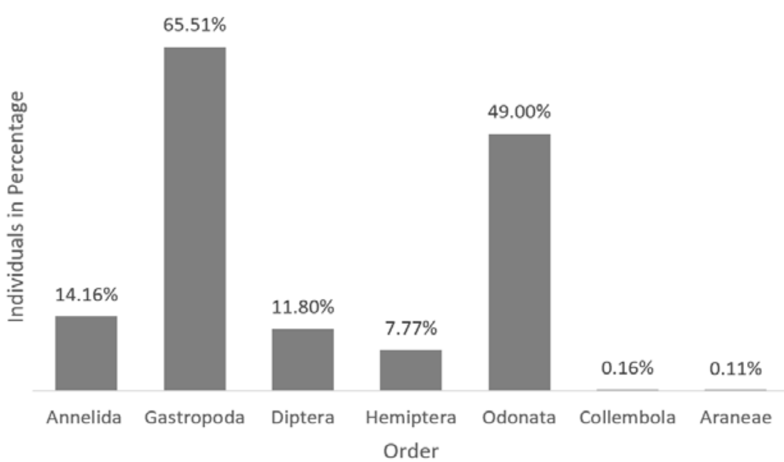

Figure 2. Taxonomic order of aquatic macroinvertebrates showing its percent composition collected in the four stream systems with Caraga State University-Main Campus

Carabao Center, areas characterized by notable upstream domestic and agricultural activities. According to Hepp et al. (2010), pollution-tolerant macroinvertebrates are likely due to runoff from domestic sewage, livestock, and agricultural operations. However, Xu et al. (2014) found that Hydrobiidae species typically thrive in environments with excellent water quality, particularly those with high levels of dissolved oxygen.

The order Gastropoda (65.51%), followed by Annelida (14.16%), Diptera (11.80%), and Hemiptera (7.77%), showed the highest abundance among macroinvertebrates (Figure 2). These organisms, which reside within the sediment, are known to tolerate organic pollution, low oxygen levels, and sediment disturbances (Amiard-Triquet & Berthet 2015). Hydrobiidae, the most abundant taxa, are typically found in moist plant debris, under rocks, among low vegetation, mulch, and fallen logs-ideal hiding spots observed at the Carabao Center. The presence of Gastropoda, Annelida, Diptera, and Hemiptera across the four creeks suggests that these species are generalists. Bhandari et al. (2018) noted that species in these orders, except Hemiptera, prefer habitats with stones, pebbles, boulders, cobbles, and gravel. Hemiptera, on the other hand, are site-specific. Additionally, most Gastropoda and Annelida species are highly tolerant of pollution. The least collected taxa belonged to the order Odonata, which, despite being generalists (Bhandari et al. 2018), are known to be facultative organisms, typically associated with moderately polluted waters (Olomukoro and Dirisu 2014).

Taxa diversity within an ecological community is assessed by considering both taxa richness (the number of different taxa present) and the evenness of their abundance. The evenness index, which ranges from 0 to 1, indicates how evenly individuals are distributed among the taxa, with a value of 1 signifying that all taxa are equally represented (Smith and Wilson 1996). An ecosystem exhibits low taxa evenness when a few species are highly dominant, while others are sparsely represented. In this study, the highest evenness index was recorded at Harrison Bridge (0.44), whereas the lowest was at Carabao Center (0.31) (Table 5). Evenness indices reflect standardized abundance, which is higher when most individuals are concentrated within a few taxa (Smith and Wilson, 1996). Moore (2013) notes a correlation between species richness and evenness: as both increase, so does the overall species diversity.

In terms of diversity, the creek in Eco-Park exhibited the highest Shannon-Weiner index value among the surveyed creeks. Nevertheless, according to Fernando's index (1998), all the creeks received very low ratings for their macro-benthic assemblages (Table 6). The low taxa richness underscores the severe impacts of impoundment on macroinvertebrates and the stress from pollution resulting from increased human activities (Arimoro et al. 2007; Latha and Thanga 2010; Edward and Ugwumba 2011; Andem et al. 2012). These factors contribute to the overall low diversity

Table 5. Biodiversity indices of four sampling areas

Biodiversity Indices	Harrison Bridge (S1)	Eco-Park (S2)	Carabao Center (S3)	Basag area (S4)
Richness	8	10	12	3
Abundance	577	300	790	134
Dominance	0.32	0.32	0.35	0.96
Shannon	1.26	1.33	1.29	0.12
Evenness	0.44	0.38	0.31	0.38

Table 6. Shannon diversity index (H') values of aquatic macroinvertebrates across the creek systems of Caraga State University-Main Campus

Sampling Area	H' value	Relative values
Harrison Bridge (S1)	1.26	Very low
Eco-Park (S2)	1.33	Very low
Carabao Center (S3)	1.29	Very low
Basag area (S4)	0.12	Very low

observed in the four areas. Specifically, these streams are used as bathing spots for domesticated animals and humans, laundry sites, and the surrounding riparian zones, where livestock like goats and carabao are grazed.

Pollution Tolerance Index, Biological Monitoring Working Party, and Family Biotic Index

The PTI and BMWP scores indicated that the water quality at all four subsampling stations is very good. However, in station S4, the macroinvertebrates collected were limited to only water striders (Hemiptera) and dragonflies (Odonata). The presence of dragonflies suggests slow-moving water, while the high abundance of water striders could imply moderate or slightly polluted water quality. In contrast, the macroinvertebrates found in stations S1, S2, and S3 were predominantly from the orders Annelida, Diptera, Odonata, and Gastropoda. These groups thrive in a wide range of water quality conditions, including moderate quality, and are particularly tolerant of poor water quality. The abundance of these organisms was attributed to the high organic matter content in the surrounding substrate and is consistent with their feeding habits as deposit feeders, making them more adaptable to environments with silting, decomposition, and varying flow rates compared to other macrobenthic groups (Olomukoro and Dirisu 2014) (Table 7).

Rivers and creeks are critical ecosystems with immense ecological significance (Nguyen et al. 2018). The health of these waterways is essential for the human communities that depend on them (Dickens et al. 2018). In this study, creek systems at Caraga State University (CSU)-including Harrison Bridge, Eco-Park, Carabao Center, and Basag area-achieved scores of 2.65, 2.76, 2.65, and 2.06, respectively. These scores indicate "Excellent Water Quality" with "No apparent organic pollution" (Table 8). These results are consistent with the PTI and BMWP assessments, confirming a very good water quality. The organisms identified at these subsampling stations are generally considered generalist and highly tolerant species. This complex composition likely stems from the stations' proximity to agricultural, residential, and commercial areas.

Interestingly, there is a conflicting result between the biodiversity and biotic indices used in this study. While the biodiversity index indicates very low diversity, suggesting poor stream health, the biotic indices imply excellent water quality, with no significant organic pollution. This low diversity across all sampling stations predominantly features moderately to highly tolerant invertebrates, reflecting threatened stream health. In contrast, healthy aquatic ecosystems typically support a wide variety of macroinvertebrate species, including those sensitive to pollution (USEPA 2023).

Assessing water quality is vital for monitoring environmental conditions and evaluating the health of CSU's ecosystems and their neighboring habitats. Degraded water quality can negatively impact aquatic life and the overall vitality of these ecosystems (Tampo et al. 2021).

Table 7. Pollution Tolerance Index and Biological Monitoring Working Party (BMWP) scores and the degree of pollution across the creek systems of Caraga State University-Main Campus

Sampling Area	PTI Score	Degree of pollution	BMWP Score	Degree of pollution
Harrison Bridge (S1)	491.43	Very Good	2,509	Very Good
Eco-Park (S2)	187.67	Very Good	1,171	Very Good
Carabao Center (S3)	360.25	Very Good	1,823	Very Good
Basag area (S4)	178.67	Very Good	661	Very Good

Table 8. Family Biotic Index (FBI) scores across the creek systems of Caraga State University-Main Campus

Sampling Area	FBI score	Water quality	Degree of organic pollution
Harrison Bridge (S1)	2.65	Excellent	No apparent organic pollution
Eco-Park (S2)	2.76	Excellent	No apparent organic pollution
Carabao Center (S3)	2.65	Excellent	No apparent organic pollution
Basag area (S4)	2.06	Excellent	No apparent organic pollution

4 Conclusion and Recommendations

This study is the first to explore and report the diversity, composition, and richness of macroinvertebrates in the tributaries of Caraga State University (CSU) in Ampayon, Butuan City, Philippines. The findings reveal that the Carabao Center tributary had the highest taxa and individuals. However, all subsampling stations exhibited very low diversity overall. Despite this low diversity, the PTI and BMWP scores indicated that the water quality across the four creek systems was very good. These results align with the FBI score, confirming that the water quality is excellent and shows no signs of organic pollution. Evaluating the overall health of CSU's creek systems with the available data is crucial, as the current analysis does not include the water's physicochemical properties and lacks associative insights. Additionally, the indices and their tolerance values used in this study were adapted from international sources, which feature different macroinvertebrate communities. Despite these constraints, the results suggest that CSU's creek ecosystems remain robust and conducive to macroinvertebrate life, indicating that the university's environmental management practices are effective.

To gain a deeper understanding of the microhabitat dynamics within the campus, it is crucial to incorporate additional parameters, such as the physicochemical properties of both water and soil. Philippine researchers also need to develop a localized biotic index tailored to assess the country's diverse freshwater ecosystems. Moreover, examining seasonal changes in macroinvertebrate diversity will enhance water quality evaluation in these streams. The study also highlights the value of using family-level identification for biomonitoring programs at CSU and similar environments. This method is cost-effective and practical, especially given these areas' limited systematic knowledge of macroinvertebrates.

5 Acknowledgement

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Statement of Conflict of Interest

To maintain impartiality in the article evaluation, MV Elvira and RA Seronay, members of the JESEG Editorial Board, did not participate in the review process of this article. The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Author Contribution

MV Elvira: Conception and design of study, analysis and interpretation of data, drafting and revision of the manuscript for significant intellectual content. LKL Abujan, CJD Singson: Conception and design of study, acquisition of data, drafting of the manuscript, analysis and nterpretation of data. RA Seronay: Analysis and interpretation of data, approval of the version of the manuscript to be published.

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