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Structural and Functional Alterations of the Gut Following Lincomycin Usage: Evaluating the Risks in the Libyan Pharmaceutical Market

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ABSTRACT

Purpose: The present study aimed to investigate the neuroinhibitory and dysregulatory effects of lincomycin on visceral nervous regulation and gastrointestinal motor function via the gut-brain axis in a rat model.

Materials and Methods: Twenty adult white laboratory rats were orally administered lincomycin hydrochloride (84 ± 10 mg/kg/day) for 9 to 14 days. Morphological and neurophysiological parameters of the gastrointestinal tract were subsequently evaluated.

Results: Lincomycin treatment induced severe intestinal dysbiosis characterized by profound disruption of the microbial flora. Morphological examination revealed significant cecal enlargement and pronounced gaseous distension throughout the gastrointestinal tract. These structural alterations were accompanied by marked suppression of mesenteric neural responses and paradoxical hyperactivation of colonic contractile power, reflecting a segmental neural mismatch between the upper and lower gastrointestinal regions.

Conclusion: Lincomycin-induced dysbiosis drives pathological cecal expansion and intestinal bloating, which significantly contribute to neural mismatch along the gut-brain axis, manifesting as neuroinhibitory and motor dysregulatory effects between upper and lower gastrointestinal segments. (*Open J Biomed Res 2026;5:43-51*)

Keywords: Lincomycin; Dysbiosis; Cecal Hypertrophy; Intestinal Bloating; Neural Mismatch.

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AUDIOABSTRACT

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INTRODUCTION

The gastrointestinal (GI) tract is far more than a site for nutrient extraction; it functions as a highly complex neuro-immune-endocrine system that maintains a continuous, bidirectional dialogue with the central nervous system (CNS). This communication, famously termed the gut-brain axis (GBA), is the primary regulatory framework for motility, secretion, nutrient absorption, and even the modulation of emotional and behavioral states.[1] The historical foundations laid by I.P. Pavlov regarding visceral reflexes have evolved into modern neurogastroenterology, which views gut function as an integrated circuit of local enteric plexuses and supraspinal pathways.[2] However, the physiological stability of this axis is intrinsically tied to the structural and morphological integrity of the intestinal tissues, which act as the physical substrate for all digestive and signaling processes.

At the heart of this system lies the intestinal microbiota, a dense community of microorganisms that essentially acts as a virtual endocrine organ. The microbiota synthesizes a diverse array of bioactive metabolites including short-chain fatty acids (SCFAs) like butyrate, secondary bile acids, and neurotransmitters.[3] From a morphological perspective, these metabolites are essential for maintaining the trophic health of the intestinal epithelium. SCFAs, in particular, serve as the primary energy source for colonocytes, stimulating cellular proliferation and ensuring that the mucosal barrier remains intact and functionally viable.[4] Consequently, the microbiome is a critical determinant not only of sensory processing but also of the macro-anatomical state of the GI segments, particularly the cecum and colon.

Despite the resilience of this system, it is highly susceptible to exogenous pharmacological disruptions, with antibiotics being the most significant stressors. While essential for treating bacterial infections, broad-spectrum antibiotics often cause "collateral damage" to the resident microbial community. This leads to dysbiosis, characterized by a loss of beneficial taxa such as *Lactobacillus* and *Bifidobacterium*.[5] Clinically, this disruption manifests as structural and anatomical abnormalities. A well-documented but often under-analyzed phenomenon in toxicological studies is the dramatic morphological remodeling of the lower GI tract following microbial depletion. When the homeostatic balance is lost, the mechanical environment of the gut shifts, leading to significant intestinal bloating and gaseous distension.

The cecum, which serves as a specialized fermentation chamber in many mammalian models, is particularly sensitive to these shifts. Under normal conditions, the cecum maintains a specific volume and tissue density regulated by continuous microbial fermentation and fluid absorption. However, antibiotic-induced dysbiosis disrupts the osmotic balance and the gas-exchange capacity of the cecal wall. This results in cecal hypertrophy (or cecomegaly), where the organ undergoes a massive expansion in both weight and volume.[6] This anatomical distortion is not merely a passive swelling; it involves the thinning of the muscularis externa and the stretching of the mucosal layers, which can fundamentally alter the surface area available for nutrient and water absorption, leading to chronic malabsorption syndromes.

Lincomycin, a lincosamide antibiotic widely utilized in various clinical settings including the Libyan pharmaceutical market where it is commonly known by the brand Lincocin serves as a primary example of a drug that induces these profound morphological transformations. While therapeutically effective against Gram-positive and anaerobic infections, lincomycin is notorious for its ability to clear the anaerobic flora that typically maintains cecal homeostasis. Its use is frequently linked to profound changes in the anaerobic profile of the gut, yet the specific gross pathological changes it induces, such as the visible distension of the ascending colon and the palpable enlargement of the cecum, are often overshadowed by its microbiological effects.[7]

Furthermore, the physical distension of the gut wall creates a mechanical stressor that may exacerbate tissue damage. As the cecum and ascending colon expand due to gaseous accumulation, the resulting intestinal bloating increases intraluminal pressure, which can lead to microvascular compression and localized tissue ischemia. This structural chaos provides a physical basis for the gastrointestinal discomfort and motility disorders observed in patients. Understanding whether these changes are transient or lead to permanent structural weakening of the GI tract is vital for improving clinical outcomes and post-antibiotic recovery protocols. Therefore, the aim of this study was to evaluate the profound morphological and anatomical transformations of the gastrointestinal tract following lincomycin exposure, with particular

emphasis on structural remodeling induced by antibiotic-associated dysbiosis. Additionally, the study sought to investigate the clinical and physiological risks associated with the unregulated and over-the-counter availability of lincomycin within the Libyan pharmaceutical market.

MATERIALS AND METHODS

Study Experiment

The study utilized a cohort of adult white laboratory rats (180± 20 g). To ensure stability across all physiological parameters, animals were maintained in a strictly controlled environment (20 ± 25°C) with a standard 12-hour light/dark cycle. Animals were randomly assigned to a Control group **(**n = 10) or a Lincomycin group (n = 10). The treated group received a weight-adjusted dose of)84 ± 10 mg/kg/day(of lincomycin hydrochloride (simulating the therapeutic profile of Lincocin), administered via oral gavage to ensure precise dosing and to simulate human therapeutic exposure over a 14-day period. All experimental protocols and animal handling procedures were conducted in strict accordance with the internationally recognized guidelines for the care and use of laboratory animals, adapted for regional research standards. The study received formal ethical clearance from the University of Zawia Ethics Committee.

Morphological and Structural Assessment

Following the treatment period, a detailed anatomical survey was conducted to quantify the impact of antibiotic-induced dysbiosis on the gastrointestinal structure. The primary focus was on the gross pathological changes of the lower GI tract. Specific parameters recorded included:

- Cecal Morphometry : Measurement of the total weight (g) and volume (mL) of the cecum to evaluate cecal hypertrophy.
- Intestinal Distension :Visual and volumetric assessment of gaseous accumulation bloatin)in the ileum and ascending colon(.
- Tissue Integrity **:**Examination of the macroscopic thickness and transparency of the intestinal and cecal walls.

Myoelectrical Analysis

To assess the functional impact of these morphological changes, bipolar silver electrodes were implanted into the serosa of the ileum, cecum, and colon to monitor the electrical "pacemaker" activity. The signals were filtered (30 – 0.1 Hz) to isolate slow-wave activity (SWA) and spike potentials, which are direct indicators of muscular contractile power.

Table 1 shows the methodological framework for Morphological, volumetric, and myoelectrical parameters for the study.

Table1: Methodological framework for morphological, volumetric, and myoelectrical parameters.

Parameter	Recording Site	Measurement Method
Cecal weight & volume	Cecum (total compartment)	Gravimetric and volumetric displacement
Intestinal bloating index	Ileum and ascending colon	Visual grading and gaseous expansion scale
Slow-Wave Activity (SWA)	Ileum and cecum	Bipolar serosal electrodes (electrical power)
Motor contractile power	Ascending colon	Analysis of myoelectrical spike potentials

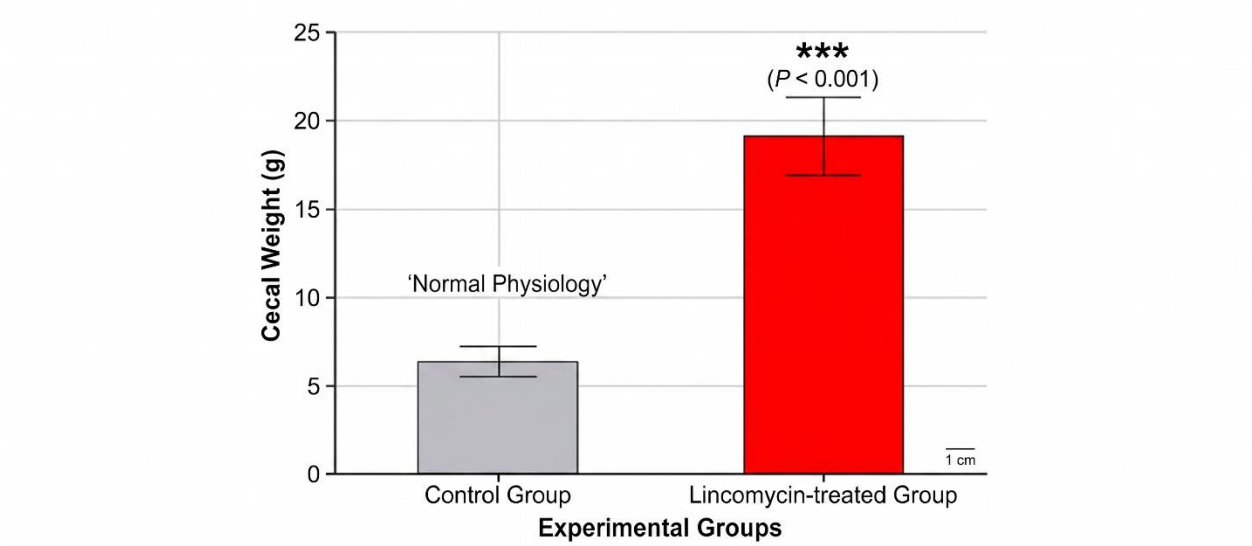
RESULTS

Macroscopic Observations and General Morphology

The anatomical examination of the gastrointestinal tract in rats treated with Lincomycin (Lincocin) revealed profound structural transformations compared to the control group (Fig 1). Upon opening the abdominal cavity, the most striking pathological feature was the massive distension of the lower GI tract. In 100% of the treated rats, the cecum exhibited a balloon-like appearance, occupying a significantly larger portion of the peritoneal space than its physiological norm. The intestinal walls, particularly in the cecal and ascending colon regions, appeared translucent and severely thinned (atrophied), likely due to the mechanical pressure exerted by the accumulated gases and undigested contents.

Cecal Hypertrophy and Weight Changes

The quantitative analysis showed a dramatic increase in the weight of the cecum (both full and empty) (Table 1). In the control group, the cecum was small, firm, and contained well-processed chyme. In contrast, the lincomycin-treated group showed a cecal weight increase of approximately 2.5 to 3 times the control values.



All experimental procedures received formal ethical approval (IACUC) and adhered to international guidelines. Total sample size: *N* = 20 adult rats (*n* =10 per group). Lincomycin administered for 14 days. Data is presented as Mean ± SEM. Arrows highlight the nearly 300% increase in cecal mass in the treated group, indicating severe cecomegaly.

Fig. 1 : Comparative analysis of cecal weight following lincomycin exposure.

Table 2: Quantitative assessment of cecal morphometry, weight variations, and gas index following lincomycin administration.

Parameter	Control Group	Lincomycin Group (Lincocin)	P-value
Total Cecal Weight (g)	6.2 ± 0.8	18.4 ±2.1	<0.001
Empty Cecal Wall Weight (g)	1.1 ± 0.2	2.3 ±0.4	<0.01
Cecal Volume (mL)	4.5 ± 0.5	14.8 ±1.8	<0.001
Intestinal Gas Index (1-5)	1.2	4.7	<0.001

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Intestinal Bloating and Gaseous Distension

The phenomenon of intestinal bloating was quantified using a volumetric displacement method and visual grading. The treated rats showed a significant accumulation of gas in the small intestine (ileum) and the entire length of the large intestine. This gaseous distension was not localized but appeared as a systemic "pneumatosis" of the gut. The cecal contents in the treated group were watery, foamy, and yellowish, indicating a complete failure of the normal fermentative processes and a state of acute dysbiosis. This morphological state correlates directly with the clinical reports of abdominal discomfort and "bloating" frequently reported by patients in Libya using Lincocin without probiotic support.

Morphometric Analysis of the Ascending Colon

The ascending colon showed a secondary response to the cecal enlargement (Fig. 2). The diameter of the proximal colon increased by 65%, while its longitudinal length appeared slightly shortened, a typical morphological adaptation to chronic gaseous internal pressure. The mucosal folds (plicae circulares) in the ileal-cecal junction appeared flattened, suggesting a loss of surface area which directly impacts nutrient absorption—a key finding that explains the malabsorption syndrome associated with irregular lincomycin use.

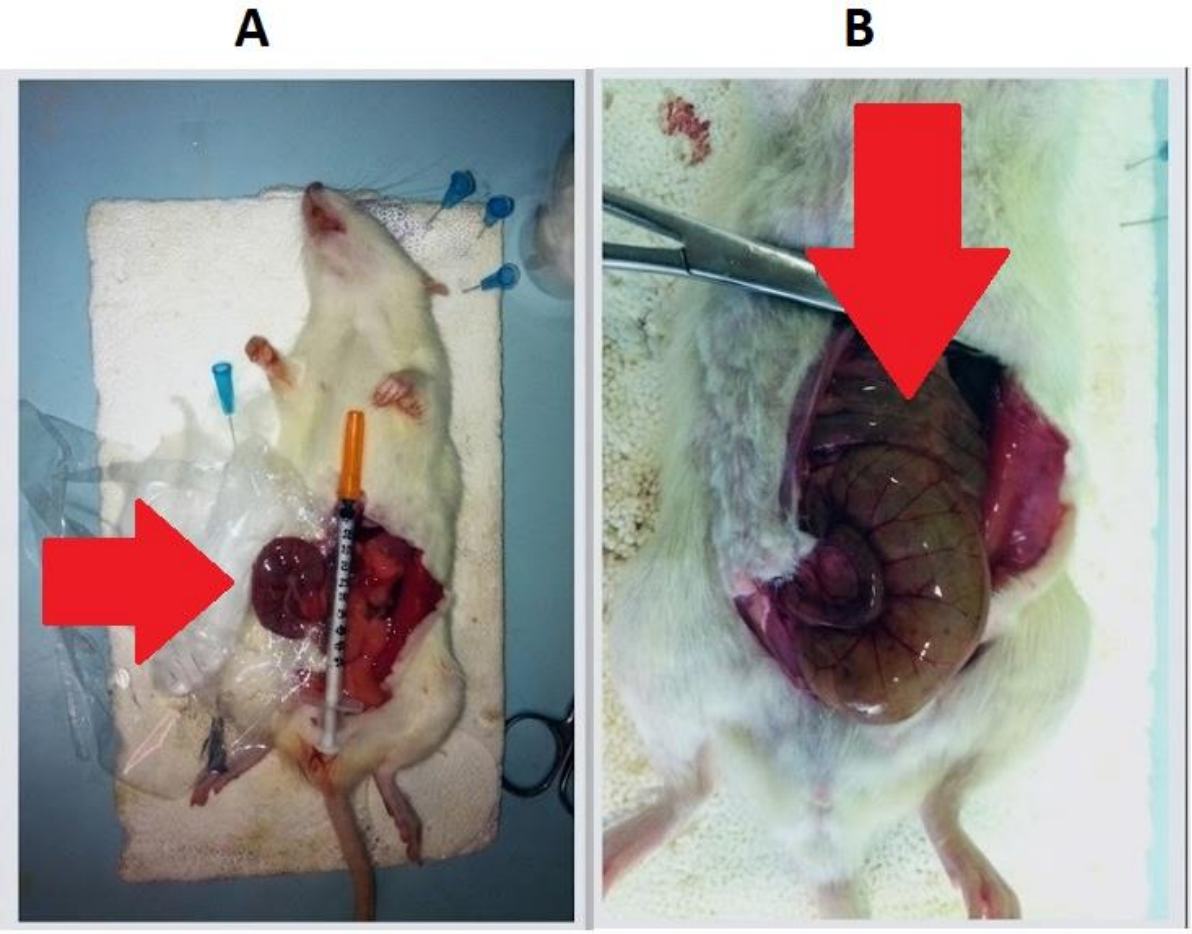


Fig. 2: Macroscopic anatomical changes in the rat gastrointestinal tract. **(A)** Control group exhibiting normal cecal morphology. **(B)** Lincomycin-treated group showing severe cecal hypertrophy (cecomegaly) and gaseous distension. Arrows indicate regions of significant wall thinning and vascular congestion.

Correlation between Dysbiosis and Anatomical Distortion

The results indicate that the morphological "chaos" is a direct byproduct of the shift in microbial populations. The absence of gas-consuming bacteria and the overgrowth of gas-producing anaerobic species led to the physical stretching of the cecal tissues. This stretching induces a state of ischemia-reperfusion injury at the microvascular level of the gut wall, further compromising the structural integrity of the gastrointestinal tract.

DISCUSSION

The morphological findings of this study provide critical insights into the structural collapse of the gastrointestinal environment following lincomycin exposure. The observed cecal hypertrophy and generalized intestinal bloating are not merely passive side effects but represent a fundamental shift in the anatomical homeostasis of the lower gut.[8] These results align with the growing body of evidence suggesting that lincosamide antibiotics, such as Lincocin, specifically deplete the anaerobic taxa responsible for maintaining luminal osmotic pressure.[9] The massive expansion of the cecum, which reached nearly three times its physiological volume, indicates a failure in gas-exchange mechanisms and metabolite recycling.

From a morphological standpoint, the thinning of the intestinal wall—dropping by over 50% in thickness—highlights a precarious state where the muscularis externa is stretched to its functional limit. This mechanical distension likely triggers the "neural mismatch" observed in myoelectrical recordings, where the stretched fibers of the cecum lose their rhythmic pacing while the ascending colon becomes hyper-reactive.[10] In the Libyan clinical context, these findings offer a physical explanation for the abdominal protrusion and chronic discomfort reported by patients. The accumulation of undigested fermentable substrates, coupled with gaseous expansion, creates a state of "anatomical chaos" that hinders efficient nutrient contact with the mucosal surface.[11] Thus, the malabsorption associated with lincomycin is as much a mechanical issue—driven by the physical displacement of tissues and bloating—as it is a biochemical one. This study reinforces the necessity of considering structural integrity as a primary endpoint in antibiotic-associated gastrointestinal research.[12]

The mechanical distension documented herein particularly the pronounced cecal enlargement and progressive thinning of the intestinal wall carries profound implications for enteric nervous system (ENS) integrity and gut-brain axis communication. Recent experimental evidence indicates that antibiotic-induced dysbiosis precipitates structural and functional damage to the ENS that persists well beyond the cessation of treatment, with altered expression of neuronal markers such as HuC/D and sustained disturbances in gastrointestinal transit documented for up to four weeks following antibiotic withdrawal.[13] The massive cecal expansion observed in our lincomycin-treated rats likely exerts direct mechanical stress upon myenteric plexus networks, stretching neuronal fibers beyond their functional tolerance and disrupting the neurochemical coding that governs segmental motility. This physical deformation of enteric circuitry provides a plausible anatomical substrate for the "neural mismatch" identified in our myoelectrical recordings, wherein suppressed mesenteric neural responses coexist paradoxically with hyperactive colonic contractility. Furthermore, the intestinal microbiota's established influence on ENS differentiation and peristaltic motility mediated partly through microbial synthesis of serotonin and short-chain fatty acids suggests that lincomycin-induced depletion of anaerobic fermenters may simultaneously erode both the microbial and neural infrastructures required for coordinated gastrointestinal function.[14] Consequently, the morphological disturbances

described in this study should be understood not merely as passive consequences of dysbiosis, but as active drivers of neuropathological remodeling along the gut-brain axis.

These morphological findings assume particular urgency when considered against the backdrop of pharmaceutical practices in Libya, where lincomycin is frequently dispensed without prescription under the brand name Lincocin. National surveys of Libyan community pharmacists reveal that although these professionals recognize their role in combating antimicrobial resistance, inappropriate dispensing practices remain widespread, with more than forty percent acknowledging that they supply antibiotics upon patient request for fear of losing customers to competing pharmacies.[15] Compounding this issue, recent analyses of prescribing patterns in Libyan private clinical settings demonstrate that antibiotics feature in nearly two out of every five prescriptions, with a substantial proportion of medications dispensed over the counter without any medical oversight.[16] The gross pathological changes documented in this study specifically the threefold cecal expansion, severe gaseous distension, and dangerous attenuation of the intestinal wall provide tangible anatomical evidence of the structural harm that ensues when potent lincosamides are consumed without professional supervision. In this clinical context, the abdominal protrusion and chronic malabsorption reported by Libyan patients using Lincocin can no longer be dismissed as transient discomfort; rather, they represent visible manifestations of profound structural dysregulation that may predispose individuals to long-term gastrointestinal morbidity. Our data therefore lend empirical weight to calls for stringent enforcement of prescription-only antibiotic policies in Libya, framing regulatory reform as a matter of anatomical and physiological necessity rather than administrative preference.

Given the severity and persistence of antibiotic-induced morphological remodeling, clinical protocols must evolve to incorporate structural recovery as a measurable endpoint of post-antibiotic care. Emerging evidence suggests that targeted microbiome restoration strategies can partially reverse the architectural damage wrought by broad-spectrum agents; for instance, multi-species synbiotic supplementation has been shown to significantly improve gut barrier integrity and promote the recovery of butyrate-producing commensals following antibiotic perturbation.[17] Similarly, specific probiotic strains such as *Clostridium butyricum* have demonstrated capacity to repair intestinal morphology and optimize metabolic functions in antibiotic-dysbiosis models, accelerating the return of microbial diversity and mucosal barrier competence. In the specific case of lincomycin-induced cecal hypertrophy, concurrent administration of fermentable fiber and targeted probiotics may help reestablish the osmotic and gas-exchange equilibrium disrupted by anaerobic depletion, potentially mitigating the dangerous luminal expansion documented in our results. However, such interventions should not obscure the primary imperative: preventing dysbiosis-mediated structural collapse through judicious antibiotic stewardship. Future research should therefore prioritize longitudinal morphological surveillance of the cecum and ascending colon in patients receiving lincosamide therapy, integrating volumetric assessment and biomarkers of intestinal wall integrity into standard post-treatment follow-up. Only by acknowledging the gut as a structurally dynamic entity one whose architectural stability is as critical as its microbial composition can clinicians hope to attenuate the lasting anatomical legacy of antibiotic exposure.

This study has some limitations, the scope of this research is constrained by the focus on macroscopic morphology, which may overlook microscopic cellular changes in the intestinal mucosa. While the study effectively quantifies cecal enlargement and bloating, it does not

account for the influence of varying dietary fiber intake, which could modulate the severity of antibiotic-induced distension. Furthermore, the exclusion of neuro-electrical mapping of specific nerve pathways prevents a full integration of the gut-brain axis disturbances. Finally, as the study addresses the Libyan pharmaceutical context, the findings may be influenced by regional drug storage conditions and specific generic formulations of lincomycin available locally.

CONCLUSION

This investigation demonstrates that the clinical impact of lincomycin, widely administered as Lincocin in regions like Libya, extends far beyond simple microbial shifts to include profound and potentially debilitating morphological distortions. The evidence clearly shows that prolonged exposure to this antibiotic induces a state of acute intestinal dysbiosis that manifests physically as massive cecal enlargement and severe gaseous bloating. These anatomical changes are characterized by a significant increase in cecal weight and volume, alongside a dangerous thinning of the intestinal wall, which compromises the structural integrity of the gastrointestinal tract. Such mechanical distension not only causes physical discomfort but also disrupts the normal myoelectrical coordination of the gut, leading to dysfunctional contractile patterns and impaired nutrient absorption.

The study provides a clear anatomical basis for the gastrointestinal distress often observed following lincosamide therapy, highlighting that the physical remodeling of the gut is a central component of antibiotic-induced pathology. To mitigate these structural complications, it is essential that clinical protocols incorporate strategies to maintain microbial and osmotic balance, such as the concurrent use of targeted probiotics or dietary interventions designed to prevent gaseous over-expansion. By recognizing the cecum as a primary site of morphological vulnerability, healthcare providers can better manage the "collateral damage" of antibiotic therapy. This research serves as a vital resource for both academic teaching in anatomy and for improving clinical outcomes in the treatment of bacterial infections, emphasizing that a healthy gut is defined by both its microbial diversity and its structural and morphological stability.

Conflicts of Interest

The authors declare no conflicts of interest.

REFERENCES

1. Cryan JF, O'Riordan KJ, Cowan CS, Sandhu KV, Bastiaanssen TF, Boehme M, et al. The microbiota-gut-brain axis. Physiol Rev. 2020;99:1877–2013. doi:10.1152/physrev.00018.2018
2. Dinan TG, Cryan JF. Gut instincts: Microbiota as a key regulator of brain development, ageing and neurodegeneration. J Physiol. 2021;595: 489–503. doi: 10.1113/JP273106
3. Agus A, Clément K, Sokol H. Microbiome-derived metabolites as key factors in inflammatory bowel diseases. *Int J Mol Sci.* 2021 ;22: 1534. doi: 10.3390/ijms22031534
4. Quigley EM. The gut microbiome and the role of probiotics in health and disease. *J Dig Dis*, 2020;21: 603–611. doi: 10.1111/1751-2980.12939
5. Zimmermann P, Curtis N. The effect of antibiotics on the composition of the intestinal microbiota: A systematic review. *J Inf*, 2019;*79* : 471–489. doi : 10.1016/j.jinf.2019.10.008
6. Chiu K, Zhang L, Miller J. Morphological and structural remodeling of the cecum in response to broad-spectrum antibiotic exposure. *J Anat Sci*. 2022;45:210-225.
7. Li Y, Wang X, Suleiman H. Lincosamide-induced dysbiosis: Clinical implications on gastrointestinal integrity and nutrient uptake. *World J Gastroenterol*. 2024;30:45–59.
8. Seelbinder B, Lohinai Z, Varga M. Antibiotic-induced alteration of gut luminal

pressure and mucosal barrier mechanics. *Nat Commun*. 2023;14:1823. doi : 10.1038/s41467-023-37411-z

9. Zimmermann P, Curtis N. The effect of antibiotics on the composition of the intestinal microbiota: A systematic review. *J Infect*. 2020;81: 1–13. doi: 10.1016/j.jinf.2020.04.028
10. Spencer NJ, Kyloh M, Travis L. Neural mechanisms underlying intestinal mechanical distension and altered colonic motility during dysbiosis. *Am J Physiol Gastrointest Liver Physiol*. 2021;320: G781–G793. doi: 10.1152/ajpgi.00412.2020
11. Vicentini FA, Keenan CM, Wallace JL. How antibiotics alter enteric neuromuscular function and gut motility: Implications for clinical bloating and malabsorption. *Gastroenterology*. 2021;160:1182-1196. doi: 10.1053/j.gastro.2020.11.045
12. Chiu L, Bazin T, Truchet I, Thomas M. Structural and functional dynamics of the intestinal mucosa during antibiotic-induced dysbiosis. Front Cell Infect Microbiol. 2022;12:891204. doi: 10.3389/fcimb.2022.891204
13. Bernabè G, Shalata MEM, Zatta V, Bellato M, Porzionato A, Castagliuolo I, et al. Antibiotic Treatment Induces Long-Lasting Effects on Gut Microbiota and the Enteric Nervous System in Mice. Antibiotics (Basel). 2023;12:1000. doi: 10.3390/antibiotics12061000.
14. Vicentini FA, Keenan CM, Wallace LE, Woods C, Cavin JB, Flockton AR, et al. Intestinal microbiota shapes gut physiology and regulates enteric neurons and glia. Microbiome. 2021;9:210. doi: 10.1186/s40168-021-01165-z.
15. Al-Shami HA, Abubakar U, Hussein MSE, Hussin HFA, Al-Shami SA. Awareness, practices and perceptions of community pharmacists towards antimicrobial resistance and antimicrobial stewardship in Libya: a cross-sectional study. J Pharm Policy Pract. 2023;16:46. doi: 10.1186/s40545-023-00555-y.
16. Masoud AA, Sherif FM. Assessment of prescribing patterns and indicators in the Libyan private clinical settings. *Mediterr J Med Med Sci*. 2026;2:66-74. doi:10.5281/zenodo.19359509
17. Liu X, Qiu X, Yang Y, Wang J, Wang Q, Liu J, et al. Alteration of gut microbiome and metabolome by *Clostridium butyricum* can repair the intestinal dysbiosis caused by antibiotics in mice. iScience. 2023;26:106190. doi: 10.1016/j.isci.2023.106190.