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Readiness Assessment for Integrating Laboratory Information Management Systems with Public Health Surveillance Systems for Effective Detection of Priority Zoonoses Outbreaks in Cameroon

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Abstract

Integrating Laboratory Information Management Systems (LIMS) with Public Health Surveillance Systems (PHSS) holds immense promise for bolstering the prompt detection and response to outbreaks of priority zoonoses. This study assesses the readiness for such integration in Cameroon, focusing on the detection of priority zoonoses. We employed a mixed-methods approach that combines quantitative data analysis and qualitative surveys with key stakeholders, which was conducted to assess the current state of LIMS, the existing PHSS, and the infrastructural and human resource capabilities. Our findings reveal significant gaps in infrastructure, technical expertise, and the existing policy framework. However, there are promising aspects, such as the existence of robust laboratory networks and a strong commitment from public health authorities to enhance disease surveillance. This readiness assessment is a critical first step toward strengthening Cameroon's public health infrastructure to manage zoonotic threats effectively. We propose actionable recommendations, such as targeted investments in infrastructure, capacity building, and policy reforms, that can pave the way for a more robust and effective public health surveillance system in Cameroon.

Keywords: *Cameroon, Information Management Systems, Surveillance, Zoonoses.*

Introduction

Zoonotic diseases, which are infections that can be transmitted between animals and humans, pose a significant public health concern in Cameroon [1]. This is due to the country's diverse wildlife, close interactions between humans and animals, and the potential for disease transmission [2]. Some zoonotic diseases are prioritized in Cameroon because of their profound impact on human health, animal health, and the economy. These diseases can have devastating consequences for both individuals and communities in the country, leading to illness, death, and economic losses [3].

In 2016, the Cameroon National Programme for the Prevention and Control of Emerging and Re-emerging Zoonotic Diseases (PNPLZER) made a significant stride. They confirmed the presence of a category of zoonotic diseases evolving in an enzootic mode within the national territory [2]. This triggered the conduct of a semi-quantitative prioritization process of zoonotic diseases of greatest national concern for Cameroon. The process, guided by a set of clearly defined criteria developed by the United States Centers for Disease Control and Prevention (CDC) [2,3], identified ten zoonotic diseases as priority zoonoses in Cameroon. These include Rabies, Anthrax, Highly Pathogenic Avian Influenza (HPAI), Ebola Virus Disease (EVD), Bovine tuberculosis (bTB), Invasive non-typhoidal Salmonella (iNTS) disease, Brucellosis, MPOX, Human African Trypanosomiasis (HAT), and Lassa fever [2].

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The background of priority zoonoses in Cameroon is closely linked to the country's agricultural practices, wildlife trade, and limited resources for disease surveillance and control [4]. Livestock farming is a crucial part of Cameroon's economy, with many rural communities relying on animals for food, income, and transportation. The proximity of humans and animals in these settings increases the risk of zoonotic disease transmission. Additionally, the illegal wildlife trade in Cameroon poses a significant threat, as it can lead to the spread of zoonotic diseases from wildlife to humans [5].

Although Cameroon has seen multiple priority zoonosis outbreaks, the nation still confronts many obstacles in putting in place efficient surveillance for these diseases [6]. Some include Limited laboratory capacity, less-than-ideal data integration processes, disjointed surveillance systems, and limited funding for monitoring and response operations [7, 8, 9]. An outstanding gap in Cameroon's disease surveillance endeavours is the lack of seamless integration between LMIS and PHSS [10, 11]. These challenges hinder the timely detection and control of priority zoonotic diseases, increasing the risk of outbreaks and their potential impact on public health and the economy [12].

Integrating LIMS and PHSS would, therefore, address the challenges faced by Cameroon in priority zoonoses surveillance. A more comprehensive and real-time picture of disease occurrence and trends can be obtained by combining laboratory data with surveillance data. This integration would enable the early detection of outbreaks of priority zoonotic diseases, enhance data quality and completeness, facilitate timely reporting and response, improve coordination among different stakeholders involved in disease surveillance and control, and promote a more coordinated and efficient response to these outbreaks [13].

However, for this integration to be successful, it is essential to assess key enabling factors such as data interoperability, existing infrastructure, human resources, policy framework, and stakeholder collaboration to 1) better understand the feasibility and readiness for integration and 2) tailor the integration process to address country-specific gaps. This study was therefore designed to assess the current landscape and readiness for integrating LIMS with PHSS in Cameroon to inform evidence-based strategies for strengthening priority zoonotic disease surveillance and advancing One Health approaches to disease control.

Materials and Methods

Study Area

This study was conducted in Cameroon. The country is located in Central Africa, with a rich biodiversity, diverse ecosystems, and a wide range of animal species. It is also characterized by complex interactions between humans, livestock, and wildlife, creating a conducive environment for zoonotic disease transmission [4]. Cameroon faces a significant burden of priority zoonotic diseases and other emerging infectious diseases that pose a threat to public health, animal health, and ecosystem stability, highlighting the importance of effective surveillance and response mechanisms [2,3].

Cameroon's public sector is composed of 4,055 public and private healthcare facilities spread across 189 health districts and 1,462 health areas. There are a total of 165 District Hospitals, 255 Medical Health Centers, 2,229 Integrated Health Centers, 5 General Hospitals, 5 Central Hospitals, and 16 Regional Hospitals in this sector [10]. Laboratories in Cameroon are classified from L1-L4 (figure 1), and the country has a mix of health system infrastructure ranging from urban centres with well-equipped facilities to rural areas with limited access to healthcare services [10].

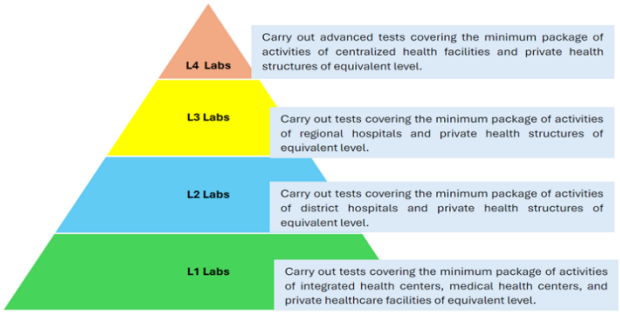

Figure 1. Classification of Laboratories in Cameroon [10].

The country also faces challenges such as limited data-sharing mechanisms, inadequate technical capacities, fragmented governance structures, and resource constraints that may hinder the integration of LIMS with public health surveillance systems [11]. However, the country also presents opportunities for enhancing collaboration, building technical capacity, and developing policies to support integrated disease surveillance efforts.

Data for this study was collected within Cameroon from:

1. The Ministry of Public Health
2. National disease surveillance and control services
3. LIMS developers (information technology [IT] facilities)
4. LIMS end users (health facilities)
5. PHSS digital platform end users

Inclusion Criteria

The study's inclusion criteria were facilities and services involved in priority zoonoses diagnosis and surveillance in Cameroon, which were enrolled after an informed consent process.

Exclusion Criteria

- Facilities and services not involved in priority zoonoses diagnosis and surveillance in Cameroon.
- Unwillingness to participate in the study

Study Design and Data Collection

This was a mixed-methods study designed to determine the effect of integrating LIMS and PHSS on Cameroon's ability to detect and respond to outbreaks of priority zoonoses.

Semi-structured key informant interviews and field visits (prospective) coupled with a review of literature and government documents (retrospective) were used to structure this study into two main thematics including:

1. The current landscape of laboratory information management systems (LIMS) and public health surveillance systems in Cameroon, including their existing infrastructure, data management practices, and technological capabilities
2. Readiness level for LIMS and PHSS integration.

We used the following matrix, conceptual framework, and technical guidelines from WHO, WHO Regional Office for Africa (WHO-AFRO), and CDC to frame the study:

1. The WHO-AFRO and CDC first and second editions of the IDSR Technical Guidelines [14,15].
2. The WHO-AFRO regional strategy for communicable diseases 1999-2003 [16].
3. The IDSR standard matrix for integrated surveillance functions and skills [17].
4. The WHO conceptual framework of surveillance and response systems [18].

In-person interviews were conducted with stakeholders (laboratory personnel, public health officials, and IT professionals) from the sampling areas, using semi-structured questionnaires to collect primary data to provide insights into the current practices, data management workflows, challenges, and

potential opportunities for integrating LIMS data with PHSS.

Statistical Considerations

The gathered data were input into Microsoft Excel. After that, an entry sheet in EPI Info 7 was made to modify the data to find associations and correlations between the variables [19]. A statistical threshold of P = 0.05 was chosen for statistical significance. The overall completeness and timeliness of the data were compared to the national guidelines' recommended norm of 80% [19]. After importing qualitative data into NVivo 12, the data were analyzed using a thematic approach. Codes were created to facilitate deductive analysis. All of the gathered data were stored on a password-protected computer that was only accessible by the investigator.

Ethical Considerations

The Cameroon National Ethics Committee granted ethical approval prior to the commencement of the study. Data was only gathered from people who gave their full consent. Prior to conducting the study, administrative authorizations were sought from the relevant divisional public health delegations, and approvals were received from the District Medical Officers.

Results

Demographic Information

A total of 240 respondents participated in the study, including 150 laboratory managers, 72 IT personnel, and 18 public health officials (Table 1).

Table 1: Demographic Information of Respondents

Variable		Frequency	Percentage
Sex	Male	128	53.3
	Female	112	46.7
Region	Adamawa	11	4.6
	Center	47	19.6
	East	18	7.5
	Far North	14	5.8
	Littoral	36	15
	North	17	7.1
	Northwest	31	12.9
	South	16	6.7
	Southwest	32	13.3
	West	18	7.5

Technical Readiness

A total of four (04) LIMS (Boabab, PlaCARD, LDMA [Laboratory Data Management Application], and BLIS [Basic Laboratory Information System], one (01) PHSS (DHIS2 [District Health Information Software 2] and three Electronic Health Record Systems (MEDCAB, DREAM & PHR [Personal Health Record]) were included as part of this study. Limited advanced LIMS infrastructure was observed in most laboratories in Cameroon, and only 40% (97/240) of laboratories involved in the survey reported having any electronic data management system (Table 2). The majority of labs still rely on manual processes for data management. Laboratories with LIMS reported varying levels of system sophistication, with the need for advanced features necessary for seamless integration with PHSS. About 80% of laboratory staff reported receiving formal

training in LIMS operation. PHSS in Cameroon was observed to be more structured but still associated with challenges in data integration and real-time reporting (Table 3).

Policy Framework Readiness

Cameroon has made progress in developing regulatory frameworks for public health data management. However, regulations specific to the integration of LIMS with PHSS are still in nascent stages. Key informants highlighted the need for clear guidelines and standards to facilitate integration.

Table 2. Current Landscape of LIMS and PHSS in Cameroon

Laboratory Level		**Level 1 Laboratories**	**Level 2 Laboratories**	**Level 3 Laboratories**	**Level 4 Laboratories**
LIMS mapping	Usage level	0.0% (0/150)	45.3% (34/75)	80.0% (8/10)	100% (5/5)
	No. of LIMS in use	0	0 - 2	0 - 2	2 - 4
	Level of integration with other systems	N/A	0.0%	0.0%	0.0%
	Frequency of data collection	N/A	Daily	Daily	Daily
	Frequency of data reporting	N/A	Monthly	Monthly	Monthly
	Training programs for users	N/A	Unstructured	Unstructured	Structured
PHSS mapping	Usage level	18.0% (27/150)	73.3% (55/75)	100% (10/10)	100% (5/5)
	No. of PHSS in use	1	1	1	1
	Level of integration with other systems	0.0%	0.0%	0.0%	0.0%
	Frequency of data collection	Daily	Daily	Daily	Daily
	Frequency of data reporting	Monthly	Monthly	Monthly	Monthly
	Training programs for users	Structured	Structured	Structured	Structured
Other Electronic Health Record (EHR) mapping	Usage level	73.3% (110/150)	52.0% (39/75)	30.0% (3/10)	20.0% (1/5)
	No. of PHSS in use	1 - 3	1 - 3	1 - 3	1 - 3
	Level of integration with other systems	0.0%	0.0%	0.0%	0.0%
	Frequency of data collection	Daily	Daily	Daily	Daily
	Frequency of data reporting	Monthly	Monthly	Monthly	Monthly

	Training programs for users	Unstructured	Unstructured	Unstructured	Unstructured
Internet connectivity	Coverage level	None: 12.7% (19/150) Minimal: 29.3% (44/150) Optimal: 58.0% (87/150)	None: 4% (3/75) Minimal: 41.4% (31/75) Optimal: 54.6% (41/75)	None: 0.0% (0/10) Minimal: 10% (1/10) Optimal: 90.0% (9/10)	None: 0.0% (0/5) Minimal: 0.0% (0/5) Optimal: 5% (5/5)
	Level of incorporation in lab processes	Minimal	Average	Advanced	Advanced
Electricity supply	Level of power stability	70.0% (105/150)	97.3% (73/75)	100% (10/10)	100% (5/5)
Usage of cloud-based data storage solutions		0.0% (0/150)	4.0% (3/75)	60.0% (6/10)	80.0% (4/5)
Utilization of data analytics and visualization tools		0.0% (0/150)	64.0%% (48/75)	80.0% (8/10)	100% (5/5)
Presence of data backup and disaster recovery plan		0.0% (0/150)	32.0% (24/75)	60.0% (6/10)	80.0% (4/5)
Utilization of artificial intelligence or machine learning for data analysis		0.0% (0/150)	0.0% (0/75)	0.0% (0/10)	100% (5/5)
Level of investment in upgrading and maintaining LIMS and surveillance systems		Limited/low priority	Limited/low priority	Medium	Medium
Usage of barcoding or RFID technology for sample tracking		0.0% (0/150)	4.0% (3/75)	30.0% (3/10)	20.0% (1/5)
Usage of telemedicine and teleconsultation services for data sharing		0.0% (0/150)	0.0% (0/75)	0.0% (0/10)	20.0% (1/5)

Table 3: Readiness Level for LIMS and PHSS Integration

Existing infrastructure									
		LIMS				**PHSS**	**EHR-S**		
		BLIS	**PlaCARD**	**LDMA**	**Baobab**	**DHIS2**	**MEDCAB**	**DREAM**	**PHR**
Availability in healthcare facilities		14.9% (7/47)	21.3% (10/47)	40.4% (19/47)	23.4% (11/47)	40.4% 97/240	28.8% (44/153)	37.3% (57/153)	33.9% (52/153)
Utilization rate (mean % of processes covered)		85.1% (74/87)	90.8% (79/87)	79.3% (69/87)	74.7% (65/87)	42.5% (37/87)	24.1% (21/87)	32.1% (28/87)	21.8% (19/87)
interoperability of existing	Data exchange protocols	66.7% (8/12)	58.3% (7/12)	41.7% (5/12)	58.3% (7/12)	58.3% (7/12)	33.3% (4/12)	41.7% (5/12)	33.3% (4/12)

systems (system aspects)	Software compatibility	58.3% (7/12)	58.3% (7/12)	41.7% (5/12)	50.0% (6/12)	58.3% (7/12)	41.7% (5/12)	41.7% (5/12)	33.3% (4/12)
	Hardware Compatibility	91.7% (11/12)	91.7% (11/12)	91.7% (11/12)	91.7% (11/12)	91.7% (11/12)	91.7% (11/12)	91.7% (11/12)	91.7% (11/12)
Cloud-based storage capabilities		100% (10/10)	90.0% (9/10)	90.0% (9/10)	90.0% (9/10)	100% (10/10)	60.0% (6/10)	70.0% (7/10)	60.0% (6/10)
Real-time alerting and notification capabilities		72.7% (8/11)	63.6% (7/11)	72.7% (8/11)	72.7% (8/11)	81.8% (9/11)	54.5% (6/11)	54.5% (6/11)	54.5% (6/11)
Technical support capabilities		90.0% (10/10)	90.0% (9/10)	80.0% (8/10)	90.0% (9/10)	90% (9/10)	80.0% (8/10)	70.0% (7/10)	70.0% (7/10)
System performance monitoring		83.3% (10/12)	75.0% (9/12)	58.3% (7/12)	66.7% (8/12)	83.3% (10/12)	53.3% (7/12)	58.3% (7/12)	50.0% (6/12)
System maintenance capabilities		77.8% (7/9)	77.8% (7/9)	66.7% (6/9)	88.9% (8/9)	88.9% (8/9)	77.8% (7/9)	66.7% (6/9)	77.8% (7/9)
System adaptability for future needs		90.0% (9/10)	90.0% (9/10)	80.0% (8/10)	90.0% (9/10)	90.0 (9/10)	60.0% (6/10)	40.0% (4/10)	40.0% (4/10)
Technical compatibility with IT infrastructure		90.0% (9/10)	90.0% (9/10)	90.0% (9/10	90.0% (9/10)	90.0 (9/10)	90.0% (9/10	90.0% (9/10	90.0% (9/10
System customization capabilities		88.9% (8/9)	88.9% (8/9)	66.7% (6/9)	77.8% (7/9)	88.9% (8/9)	77.8% (7/9)	77.8% (7/9)	77.8% (7/9)
Automated data integration capabilities		70.0% (7/10)	70.0% (7/10)	70.0% (7/10)	80.0% (8/10)	80.0 (8/10)	70.0% (7/10)	70.0% (7/10)	70.0% (7/10)
Data management practices									
Level of data standardization across systems		88.9% (8/9)	77.8% (7/9)	77.8% (7/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	77.8% (7/9)	88.9% (8/9)
Data quality assurance		77.8% (7/9)	77.8% (7/9)	77.8% (7/9)	77.8% (7/9)	77.8% (7/9)	66.7% (6/9)	66.7% (6/9)	77.8% (7/9)
Data security systems		88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)
Data quality control		87.5% (7/8)	75.0% (6/8)	75.0% (6/8)	87.5% (7/8)	87.5% (7/8)	75.0% (6/8)	75.0% (6/8)	75.0% (6/8)
Data backup and recovery systems		88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)	88.9% (8/9)
Level of Real-time data-sharing		80.0% (8/10)	80.0% (8/10)	70.0% (7/10)	80.0% (8/10)	90.0 (9/10)	60.0% (6/10)	60.0% (6/10)	60.0% (6/10)
Utilization of data analytics & visualization tools		60.0% (3/5)	80.0% (4/5)	60.0% (3/5)	60.0% (3/5)	60.0% (3/5)	60.0% (3/5)	60.0% (3/5)	60.0% (3/5)
Mean percentage of trained users		78.6% (22/28)	78.3% (29/37)	80.4% (37/46)	85.3% (35/41)	80.3% (151/188)	73.2% (71/97)	72.8 (59/81)	68.8% (53/77)
Data validation culture		80.0% (8/10)	80.0% (8/10)	80.0% (8/10)	80.0% (8/10)	80.0% (8/10)	80.0% (8/10)	80.0% (8/10)	80.0% (8/10)
Policy framework									

Data privacy policies	57.1% (4/7)	70.0% (7/10)	68.4% (13/19)	91.8% (9/11)	86.6% (84/97)	86.4% (38/44)	89.5% (51/57)	84.6% (44/52)
Data-sharing policies and agreements	42.9% (3/7)	40.0% (4/10)	47.4% (9/19)	36.4% (4/11)	62.9% (61/97)	70.5% (31/44)	73.7% (42/57)	75.0% (39/52)
Legal and regulatory frameworks for integration	28.6% (2/7)	20.0% (2/10)	10.5% (2/19)	18.2% (2/11)	76.3% (74/97)	15.9% (7/44)	15.8% (9/57)	17.3% (9/52)
Data migration strategies	57.1% (4/7)	40.0% (4/10)	31.6% (6/19)	27.3% (3/11)	63.9% (62/97)	38.6% (17/44)	31.6% (18/57)	40.4% (21/52)
Integration project governance structure	28.6% (2/7)	20.0% (2/10)	21.1% (4/19)	18.2% (2/11)	79.4% (77/97)	20.5% (9/44)	14.0% (8/57)	15.4% (8/52)
Change management strategies	14.3% (1/7)	10.0% (1/10)	5.3% (1/19)	9.1% (1/11)	14.4% (14/97)	4.5% (2/44)	3.5% (2/57)	3.8% (2/52)
Stakeholder engagement								
Level of stakeholder engagement	65.0% (156/240)				98.3% (236/240)	39.2% (94/240)		

Discussion

Cameroon's public health infrastructure has significantly improved in recent years, with the establishment of a network of laboratories and surveillance systems dedicated to monitoring priority zoonotic diseases. The country has made significant progress in enhancing its capacity to diagnose and respond to these diseases. However, despite these advancements, there are notable gaps that need to be addressed to strengthen the effectiveness of public health surveillance for zoonotic diseases in Cameroon.

As seen in this study, one of the key challenges facing Cameroon's public health infrastructure is the lack of robust data-sharing mechanisms and coordination between different components of the surveillance systems. In this study, LIMS was observed to be absent in Level 1 laboratories. This, among other observed challenges such as no (12.7%) to limited (29.3%) internet coverage, absence of cloud-based data storage solutions, and limited investment in LIMS and PHSS, among others, especially at these laboratories, could pose a significant setback to the rapid detection of outbreaks of priority zoonoses since a considerable amount of these outbreaks tend to occur frequently within communities at the primary healthcare level [20].

Also, silos of unshared data were observed within various public health institutions and laboratories, and this could be responsible for the paucity of country-specific epidemiological data over the years for some priority zoonoses such as Brucellosis and Salmonellosis [21, 22, 23].

This study observed significant gaps (limited technical capacity of existing LIMS, inadequate data management practices, and limited policy framework) in data integration in the country. These could potentially hamper the timely sharing of critical data on disease trends, outbreaks, and emerging threats and consequently impede the swift detection and response to zoonotic disease outbreaks [24].

Moreover, the existing surveillance systems in Cameroon, though functional, are not fully equipped with the necessary technological capabilities to support real-time data sharing and analysis of existing data. Incompatible information management systems that characterize the surveillance system hinder the seamless integration of LIMS and PHSS, limiting the ability to leverage data for early

detection and response to zoonotic diseases [10].

In addition to technological limitations, human resource constraints pose a significant challenge to the effective integration of LIMS and PHSS in Cameroon. Adequate and well-structured comprehensive training and capacity-building programs for laboratory personnel, epidemiologists, and public health officials are needed to ensure the successful integration of LIMS with PHSS. Without a skilled workforce capable of effectively utilizing integrated systems, the potential benefits of enhanced surveillance for zoonotic diseases may remain unrealized [25].

Furthermore, it was observed that standardized protocols required for data sharing, privacy protection, and information security were limited, which could pose a risk to the integrity of surveillance data [26]. Establishing clear guidelines and protocols for data management and sharing is crucial to maintaining confidentiality while facilitating collaboration and information exchange between laboratories and public health institutions. Summarily, the following key areas were identified for review to increase the readiness level:

- **Technological investments**: Upgrade existing LIMS and PHSS infrastructure to support interoperability.
- **Capacity building**: Implement continuous training programs for laboratory and public health personnel.
- **Policy and regulatory frameworks**: Develop and enforce standardized protocols for data exchange and system integration.
- **Stakeholder Collaboration**: To support integration efforts, Foster partnerships between governmental agencies, international organizations, and private sector stakeholders.

Conclusion

The readiness of Cameroon to integrate LIMS with PHSS for effective detection of zoonotic disease outbreaks is currently limited by several factors, including inadequate infrastructure, technical capacity, and regulatory frameworks. However, with strategic investments in technology, capacity building, and policy development, Cameroon can significantly enhance its ability to detect and respond to zoonotic disease outbreaks. By harmonizing data management processes, Cameroon can improve its capacity to conduct risk assessments, track disease trends, and allocate resources efficiently to detect and rapidly respond to these outbreaks. Through investments in infrastructure, capacity building, and regulatory frameworks, Cameroon can strengthen its public health surveillance systems and improve its ability to respond promptly to zoonotic disease threats, ultimately safeguarding the health and well-being of its population. This proactive approach would contribute to strengthening the country's disease surveillance and response capabilities, consequently contributing to the overall enhancement of global health security.

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Conflict of Interest

The authors wish to declare no conflict of interest in this manuscript.

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