

Logistical resilience and digital transparency in airport supply chains: drivers for enhancing operational sustainability at Queen Alia International Airport

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Abstract

Airports are extremely important logistical facilities that facilitate economic resiliency and sustainable development. This paper is an exploration of how the logistical resilience, digital transparency and stakeholder integration can affect operational sustainability in the air cargo supply chain at Queen Alia International Airport (QAIA) in Jordan. A structured questionnaire was used to collect data in a quantitative, cross-sectional design by using a structured questionnaire on managerial and operational professionals as the main stakeholders in the supply chain of major airports. The proposed relationships were tested using the multiple regression analysis. The results reveal that the three factors significantly contribute to the positive impact on operational sustainability, and logistical resilience is the strongest predictor. Digital transparency promotes efficiency and coordination because it improves the visibility of information, and stakeholder integration also improves collaborative governance and responsiveness to operational issues. The research is significant to the literature of sustainability and management of the airport because it confirms an integrated framework that integrates airport logistics as a dynamic economic heritage asset. In practice, the findings offer knowledge to airport authorities and policymakers who intend to make airport supply chain operations more sustainable in the long-term.

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1. Introduction

Airports are essential links in the international logistics systems, which are transport hubs as well as strategic infrastructures that support the national economic resilience and sustainable development [1]. In present-day global economy, the air cargo supply chains have gained a lot of importance because they have taken care of high value, time sensitive and perishable products. But at the same time, these supply chains are vulnerable to mounting uncertainties that are caused by the volatility of global trade, geopolitical upheavals, pandemics, climate risks, and lightning-fast technology change [2]. In this space, the establishment of long-term operational

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sustainability of airport supply chains has become a strategic agenda of both policymakers and actions by logistics practitioners [3]. In view of sustainable development, the current day airports can be viewed as an economic and infrastructural legacy of a country, the collective investments, institutional capacities, and decades-long expertise in logistics [4]. To maintain and improve this tradition, one needs to adopt dynamic approaches that do not interfere with the functioning, ecological duties, and maintainability of the system. Such integrative approaches are the focus of the journal *Heritage and Sustainable Development (HSD)* in which heritage assets should not be perceived as unchangeable legacies, but dynamic systems that need to change sustainably to guarantee a future-oriented generation [5]. This dilemma is a case of the Queen Alia International Airport (QAIA) in Jordan. QAIA is the most important international entry point of the country and one of the largest regional logistic centers that contribute to the promotion of trade processes, tourism and economic relations [6]. Even though the theme of airport efficiency and environmental performance has now been investigated by previous research, the increasingly advanced nature of the air cargo operations dictates that the analysis should be done in a more sophisticated manner, including the notions of resilience, digitalization, and inter-organizational coordination [7]. To be more precise, the topic of logistical resilience, digital transparency, and integration with stakeholders has not been properly studied in connection to achieving sustainable airport supply chain processes, especially in emerging economies [8].

Logistical resilience has gained prominence as a core capability enabling supply chains to anticipate, absorb, adapt to, and recover fast following disruptions [9]. In the context of the airport cargo ecosystem, various actors include airport authorities, customs agencies, airlines, freight forwarders, and ground handlers, resilience is not only a technical quality, but an organizational and systemic quality [10]. Aiding resilience, digital transparency has gained significant importance as a facilitator of contemporary logistics due to the implementation of the latest information systems, real-time monitoring tools, and data-sharing systems [11]. The increased transparency facilitates interaction, minimizes time losses and facilitates evidence-based decision-making, which is directly related to sustainability outcomes [12]. Furthermore, the idea of stakeholder integration, which implies cooperation, trust, and mutual goals between supply chain participants, is becoming an established requirement towards resilience and sustainable performance in the complex logistics setting [13]. Although there has been an increasing number of international publications about digitalization and supply chain sustainability, empirical findings relating to the relationship between these drivers in the airport cargo supply chains, especially in the Middle East and Jordan setting, are still scarce [14]. This loss limits the formulation of context-driven policies that would integrate sustainability in operations with the national developments and conservation of the vital logistic heritage. The need to fill this gap becomes particularly topical with reference to QAIA due to the strategic intention of Jordan to become the regional logistics and transport hub and remain committed to sustainability and environmental standards [15].

The research question will therefore be the effect of logistical resilience, digital transparency and the integration of stakeholders on the operational sustainability of the supply chain of air cargo at Queen Alia International Airport. The use of quantitative methods and the foundation of the analysis based on sustainable development and heritage discourse make it easier in terms of HSD to enable the study to contribute to the understanding of how the contemporary drivers of management can help the transformation of the crucial logistics infrastructure in a sustainable manner. It is believed that the results will be practical to the airport authorities, policymakers and supply chain stakeholders that seek to improve the sustainability of their operations at the same time ensuring that they do not compromise the long-term economic heritage of the airport logistics systems.

2. Literature review and theoretical background

2.1. Operational sustainability in airport supply chains

Operational sustainability has come out as a multidimensional concept that includes economic efficiency, operational reliability, and environmental responsibility in the supply chain systems [16]. Operational sustainability in the airport logistics context is the ability of the airport to have stable, efficient, and ecologically conscious cargo operations and be able to respond properly to internal and external pressures [17]. Airports can

be viewed as sophisticated socio-technical systems in which a failure of one element e.g. the customs clearance, ground handling or information flows may spread across the whole supply chain in quick succession [18].

The existing research on airport sustainability has been largely based on the environmental indicators, including carbon emissions, energy usage, and waste disposal [19]. Although these dimensions are still of paramount importance, the current studies suggest that operational and resilience-based indicators should be integrated to obtain the comprehensive view of sustainability in airport supply chains [20]. This larger understanding is in line with the sustainable development school of thought that is looking at critical infrastructure as not merely the active assets but also long term economic and logistic heritage of a nation that must be maintained and developed over the years [21].

2.2. Logistical resilience

Logistical resilience is described as capacity of supply chain to foresee/endure shocks, adjust to new environments and rapid recovery to stable or better operational condition [22]. Resilience is essential specifically in the airport cargo environment as there is a lot of reliance on simultaneous processes that involve many independent stakeholders [23]. Shocks like severe weather conditions, international epidemics, security breaches, or system malfunctions, could greatly undermine the performance and sustainability results of airport cargo [24]. Supply chain resilience has theoretical underpinnings of the systems theory and contingency theory, in which resilience has been viewed as adaptability, redundancy, and flexibility [25]. Empirically, it is indicated that robust logistics systems play a positive role in ensuring continuity of operations, cost-effectiveness and reliability of service delivery that are crucial in sustaining operations [26]. Rigorous measures like diversified logistics routes, backup plans, and quick recovery guidelines in the context of the airport are identified to increase the long-term stability in operational activities and the trust of the stakeholders [27].

2.3. Digital transparency

Digital transparency the access, accuracy, and real-time availability of supply chain-related logistical information via integrated digital platforms and technologies [28]. The recent developments in digital technologies such as the Internet of Things (IoT), blockchain, and sophisticated information systems have revolutionized the air cargo supply chains by providing end-to-end visibility and data-driven decisions [29]. Theoretically, digital transparency will be based on the information processing theory, which assumes that organizations with a high level of uncertainty will need improved information flows to attain effective coordination and performance [30]. Digital transparency enables supply chain coordination between the customs authorities, airport operator, airlines, freight forwarders and ground handlers in an airport supply chain resulting in less delays, errors and inefficiency. Empirical evidence shows that increased digital transparency enhances operational consistency and facilitates environmental sustainability through the optimization of resource use and minimization of unnecessary cargo dwell time [31]. Digital transparency is nowadays becoming a critical facilitator of logistical resilience and operational sustainability when dealing with a complex logistics ecosystem [32].

2.4. Stakeholder integration

Stakeholder integration is the level of interaction, coordination and alignment of strategy amongst participants of a supply chain network [33]. High levels of integration are necessary in airport cargo supply chains because both operations are dependent on each other and because of the variety of different stakeholders involved. Based on the relational exchange theory and the network theory, stakeholder integration focuses on the use of trust, common goals, and information exchange as mechanisms that contribute to high performance and sustainability in the long term [34]. Empirical evidence proves that the relationships of supply chain that are integrated help to enhance responsiveness, decrease the operational risk, and the performance of sustainability. Stakeholder integration in the airport environment can assist with the coordination of disruption response, the implementation of digital solution, and the enhancement of governance frameworks within the logistics ecosystem [35]. Therefore, the concept of stakeholder integration is not merely a management practice but also

a structural facility, which supports sustainable development and sustainability in the critical infrastructure systems.

2.5. Research gap

Even though previous studies have already studied the independent role of logistical resilience, digital transparency, and stakeholder integration, there is a scarcity of empirical studies on the joint effect of these factors on operational sustainability in the airport cargo supply chains, especially in an emerging economy. Besides, not many studies have explicitly located the issue of airport logistics systems as the part of economic heritage that needs sustainable development-oriented management. Filling this gap, this study will incorporate these constructs into a single framework of analysis to find their influence on operational sustainability of Queen Alia International Airport, which will help in expanding the current theory and providing context-specific knowledge, consistent with the context of Heritage and Sustainable Development.

3. Research model and hypotheses

Building on the theoretical foundations of supply chain resilience, information processing theory, and stakeholder integration frameworks, this study proposes an integrated research model to examine the determinants of operational sustainability in airport supply chains. The model conceptualizes operational sustainability as a strategic outcome influenced by organizational capabilities, digital enablers, and inter-organizational relationships within the air cargo ecosystem.

3.1. Research model

Operational Sustainability of the Airport Supply Chain is a dependent variable proposed as the research model. It is modeled as multidimensional construction that can be applied in measuring the capacity of the airport to maintain efficient, reliable, resilient, and environmentally responsible cargo operations in the long-term [16]. Consistent with the concept of sustainable development, this construction embodies the equilibrium between economic performance, operational sustainability and environmental responsibility in critical logistics infrastructure.

The following three independent variables are postulated to have a direct effect on the operational sustainability:

1. Logistical Resilience, which is the ability of the supply chain to predict, absorb, adjust to and respond to disruptions [36].
2. Digital Transparency, which indicates the level of accessibility of real-time, precise and integrated information to authorized stakeholders throughout the supply chain [32].
3. Stakeholder Integration, which refers to the extent of strategic cooperation, integration, and trust between the important players in the airport cargo ecosystem [35].

The model assumes that each of the independent variables is related directly to operational sustainability. This is based on the previous empirical data that resilient logistics systems, clear digital infrastructures, and connected stakeholder relationships promote supply chain performance and sustainability outcomes separately. The proposed research model is described in Figure 1.

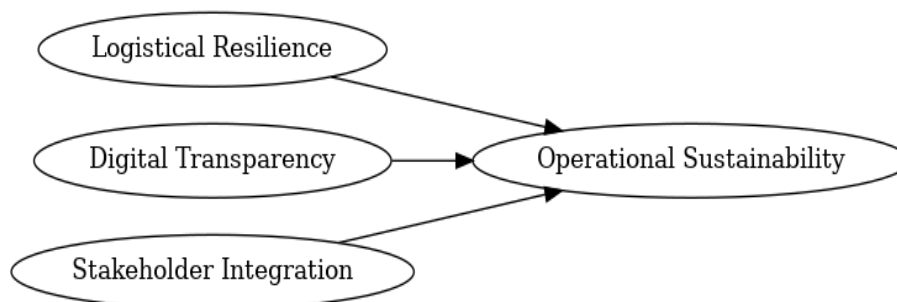


Figure 1. Proposed research model

3.2. Hypotheses development

3.2.1. Operational sustainability and logistical resilience

Logistical resilience allows supply chains to be operationally resilient and recover quickly to disruptions to minimize performance volatility and long-term operational risks [37]. The resilience mechanisms in airport cargo supply chains, including contingency planning, diverse logistics routing, and quick response are extremely important in ensuring continuity of reliable and efficient operations in case of uncertainty [38]. Strong logistics networks have also been associated with enhanced environmental performance by minimizing waste, delays and emergency induced inefficiencies. Based on this, there is an expectation of positive impacts when there are increased levels of logistical resilience on the operational sustainability of the airport supply chains.

H1: There is a significant and positive influence of logistical resilience on the operational sustainability of the airport supply chain.

3.2.2. Online accountability and financial viability

Digital transparency improves the quality and speed of flow of information among the participants of the supply chains, allowing them to coordinate better, minimize delays, and make better-informed decisions [39], [40]. Within the airport setting, digital platforms that are integrated enable real-time cargo monitoring, enhance the process of clearance of customs, and enable proactive allocation of resources [41], [42]. Empirical evidence has shown that digital transparency improves the sustainability outcomes through efficient utilization of resources and reduction of environmental impacts because of operational inefficiency [43]. Thus, increased digital visibility is likely to sustain the airport supply chain operations.

H2: Digital transparency introduces a positive and significant impact on the operational sustainability of the airport supply chain.

3.2.3. Stakeholder integration and operational sustainability

The integration of stakeholders enhances the cooperation between organizations and harmonizes the interests of supply chain members in the attainment of their operational goals [35]. In the airport cargo ecosystems, successful integration contributes to the ability to solve problems collectively, coordinated reactions to disruptions, and the acceptance of mutual sustainability practices [34]. Both theoretical and empirical evidence shows that integrated supply chain relationships enhance both operation performance and long-term sustainability [33], [44]. The increased rates of stakeholder integration should, therefore, have a positive impact on operational sustainability.

H3: The operational sustainability of the airport supply chain is positively and significantly influenced by the stakeholder integration.

3.2.4. Model implications

The model suggested implies the comprehensive perspective on the airport supply chain sustainability through the incorporation of resiliency, digitalization, and stakeholder partnership in the single analytical package. The research provides insight into the sustainable development world with the contribution to its discourse because by experimenting with these assumptions in the project Queen Alia International Airport, it presents the way modern management drivers may be used to improve the long-term sustainability of a highly important logistics heritage asset.

4. Methodological

4.1. Research design

The paper is quantitative research design that employs a cross-sectional survey to empirically address the impact on operational sustainability of logistical resilience, digital transparency and stakeholder integration in the air cargo supply chain at Queen Alia International Airport (QAIA). Quantitative design is suitable given the aim

of the study to test propose hypothesized relationships between latent constructs and evaluate the size and level of their consequences [45], [46], [47]. The cross-sectional design will enable collected homogenous data of different stakeholders at a single point and provide a clear image of current operations and sustainability level of the airport supply chain ecosystem [48]. The research is based on the positivist research paradigm which lays more stress on objectivity, measurement, and statistical analysis to describe the relationships of variables [16]. The provided paradigm is related to the prior empirical research on resilience of supply chains, digitalization, and sustainability, particularly in the conditions of intricate logistics and infrastructure such as on airports [49].

4.2. Population and sample

The sample population will include all the key players in the air cargo supply chain of Queen Alia International Airport, and it is estimated that this population has approximately 90-95 organizations. These organizations are the airport authority, customs and regulatory agents, airlines, freight forwarders, ground handling organizations, and the logistics service providers. The targeted people in these organizations are managerial and operational experts with direct information of cargo operations, digital systems, and inter-organizational coordination processes [50], [51]. The sampling method used was a mixed one because the various stakeholder groups that are involved in the airport supply chain had to be adequately represented. Purposive census sampling was used with the main regulatory and operational units, namely the airport authority and the customs, because they have strategic and systemic positions. Concurrently, larger groups of stakeholders such as freight forwarders and airlines were selected through stratified random sampling to ensure the proportion of sample in the organization categories [52]. The last sample was to have about 50 organizations and a target number of 90-110 individual survey responses of qualified managerial and operational people. This is a reasonable size to perform a multivariate statistical analysis that incorporates multiple regression analysis and structural equation modeling, (SEM), as suggested in previous empirical research of supply chain [53].

4.3. Research instrument

The structured questionnaire was designed based on the valid scales and other empirical studies in the field of supply chain resilience, digitalization, cooperation with stakeholders, and sustainability to gather information [54]. The questionnaire was expounded in a manner that ensured that it was content valid, clear and context relevant to the airport logistics setting.

This tool consists of five large sections:

Section A: Demographic and organizational profile (what sort of organization, position, years of experience).

Section B: Logistical Resilience (independent variable) was measured using multiple items, which included preparedness, adaptability, and recovery capabilities.

Section C: Digital Transparency (independent variable), the data was gathered through the assistance of the items related to real-time visibility, system integration, and access to data.

Section D: Stakeholder Integration (independent variable), which was observed through measurement by items that were related to collaboration, trust, coordination, and shared objectives.

Section E: Operational Sustainability (dependent variable) that will be measured on the indicators that consider such aspects as efficiency, reliability, environmental performance, and resilience.

The rating of all the items of perception was on a five-point Likert scale with the range of 1 (Strongly Disagree) to 5 (Strongly Agree). The Likert-type scale can be applied in the supply chain and sustainability studies universally due to its reliability and application in the evaluation of latent constructs [55]. In as much as possible, respondents also were encouraged to use objective indicators of operations (e.g., cargo dwell time, on-time performance) to give strength to responses.

4.4. Data analysis

The analysis of data was done with the help of the necessary statistical software and a multi-stage analytical process. First, the demographic characteristics of the respondents were summarized with the help of the

descriptive statistics that were applied to identify the central tendency, as well as the dispersion of the variables applied in the study [56]. Secondly, reliability was assessed by Cronbach alpha in the measuring scales where the figure exceeding the acceptable level would show that there is satisfactory reliability [57]. In order to validate the study hypotheses, multiple regression analyses as well as structural equation modeling (SEM) were applied. The methods allow studying the direct correlations between independent variables (logistical resilience, digital transparency, and stakeholder integration) and the dependent variable (operational sustainability), controlling errors in measurement and the existence of construct correlations among measures [58]. SEM, specifically, can be used with complicated models that have several latent variables and have been used extensively in sustainability and supply chain studies [59], [60]. The level of statistical significance was evaluated at a traditional level (≤ 0.05). The model fit measures and the power of the explanation were assessed to verify the strength and the validity of the empirical data. The selected analytical methodology facilitates the aim of the study to offer evidence-based evidence concerning the motivation of operation sustainability in airport supply chains.

5. Results

5.1. Descriptive statistics

The information given in this section will be the descriptive statistics of the study variables to give an overview of the perception of the respondents about logistical resilience, digital transparency, stakeholder integration, and operational sustainability in the air cargo supply chain at Queen Alia International Airport (QAIA). The general tendencies and variability of the acquired data must be determined with the help of the descriptive analysis before testing the hypothesis. Table 1 has summed up the mean values and standard deviations of constructs of the study. The findings suggest that the overall data of respondents is that the level of implementation of the dimensions studied is moderate to high, which is relatively a mature operational environment.

Table 1. Descriptive Statistics of Study Variables

Variable	Mean	Standard Deviation
Logistical Resilience	3.87	0.62
Digital Transparency	3.74	0.68
Stakeholder Integration	3.81	0.65
Operational Sustainability	3.89	0.60

The operational sustainability mean score ($M = 3.89$) indicates a rather high degree of perceived sustainability in the cargo operation of QAIA, namely, in the aspects of reliability and efficiency. The logistical resilience mean value was also high ($M = 3.87$), which indicates that airport supply chain displays a decent ability to react and recuperate in case of disruptions. On the same note, stakeholder integration ($M = 3.81$) and digital transparency ($M = 3.74$) represent a positive perception but the latter suggests that even more is possible in terms of digital integration and system interoperability.

5.2. Reliability analysis

Cronbach alpha coefficients of the measurement scales were derived to determine the internal consistency of the measurement scales. Reliability analysis serves as an important procedure in the process of validating the measurement instrument as well as responding in the same manner regarding a given construct across items when the measure means the same thing.

Table 2. Reliability results

Construct	Number of Items	Cronbach's Alpha
Logistical Resilience	6	0.88
Digital Transparency	5	0.86
Stakeholder Integration	6	0.90
Operational Sustainability	7	0.89

The values of all alphas of Cronbach are more than the recommended level of 0.70, which suggests that the internal consistency and the acceptable level of reliability of all constructs are high. These findings indicate that the questions in the questionnaire are reliable in the measurements of their corresponding latent variables and that they can be further hypothesized.

5.3. Hypotheses testing

To check the hypotheses put on the table, multiple regression analysis was undertaken where the dependent variable was operational sustainability and logistical resilience, transparency in digital form, and stakeholder integration were the independent variables. This method of analysis enables the evaluation of the contribution of each of the predictors individually with the effects of other variables in the model factored out.

Table 3. Results of hypotheses testing

Hypothesis	Path	β	t-value	p-value	Result
H1	Logistical Resilience → Operational Sustainability	0.41	5.98	<0.001	Supported
H2	Digital Transparency → Operational Sustainability	0.29	4.21	<0.001	Supported
H3	Stakeholder Integration → Operational Sustainability	0.33	4.87	<0.001	Supported

The findings show that logistical resilience positively influences operational sustainability (p-value=0.001, $\beta=0.41$) the most, which confirms H1. In addition, a considerable positive impact is shown by digital transparency, which confirms H2, whereas stakeholder integration has a very strong positive impact, which proves H3. The total model accounts for a significant percentage of variation in operational sustainability ($R^2 = 0.62$), which means high explanatory ability and power.

6. Discussion

The work has discussed the effects of logistical resilience, digital transparency, and stakeholder integration on operational sustainability in air cargo supply chain at QAIA. The research findings obtained are very encouraging to the proposed research model and this supports the aspect that sustainability in airport logistics is a multidimensional outcome influenced by organizational capabilities, digital enablers and collaborative relationships. The results show that logistical resilience is the strongest predictor of operational sustainability. This is consistent with previous studies that assert that resilient supply chains are in a better position to ensure continuity, reliability and efficiency during disruptive situations. Quick recovery of disruptions in the airport cargo operations reduces cascading inefficiencies and contributes to long-term sustainability goals. These results support the importance of resilience as a precursor ability to support critical logistics infrastructure as a national economic heritage. Online Publicity and Business Survivability. The strategic importance of digitalization to airport supply chains is confirmed by the huge impact of digital transparency. According to the information processing theory, with more visibility of information, the coordination is improved and decision-making in uncertain situations is improved. It has been proven empirically that integrated digital platforms reduce delays, environmental inefficiencies thereby leading to sustainable operations. One of the greatest facilitators of efficiency and environmental responsibility in QAIA environment is digital transparency. The findings also emphasize the role of integration of stakeholders in attaining sustainable airport operations. Good cooperation and trust with the chain partners of the supplier enhances close coordination with the response to disruption and implementation of common practices aimed at sustainability. The findings are aligned with other theories like the network and relational exchange theories which consider collective governance as a drive to long-term performance and sustainability.

7. Implications and conclusion

7.1. Implications

The study adds to the sustainability and supply chain literature by empirically demonstrating the presence of a single framework involving resilience, digital transparency, and collaboration among stakeholders. The fact that

the analysis is incorporated into the heritage and sustainable development discourse extends the theoretical perspectives of sustainable infrastructure management that is already in place.

The implications on practitioners and policymakers imply the need for focus on resilience planning, digital infrastructure, and collaborative governance mechanisms investment. Sustainability of the findings associated with the sustainable development of airport supply chains can be also improved with the help of the implementation of regulatory frameworks that can contribute to information sharing and inter-organizational coordination. The research has weaknesses such as being cross-sectional and the single case study. The next research can adopt a longitudinal model or a comparative model as well and test other moderating factors such as regulatory support or technological maturity to provide additional insights on the topic of sustainable airport supply chain management.

7.2. Conclusion

The study marks that logistical resilience, digital transparency, and integration of the stakeholders positively and significantly influence the operational sustainability in air cargo supply chain at QAIA. The most influential ones were logistical resilience and then the stakeholder integration and the digital transparency. These findings confirm the accuracy of the developed research model and relevance of the combined approach to the sustainability of airport logistics systems. In terms of heritage and sustainable development, the results will underpin the image of airports as dynamic and economic heritage sites that should continue to adjust to global and regional demands. Enhancement of long-term value of this significant infrastructure will be achieved through enhancement of sustainability of operation through resilience, digitalization and collaboration.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests that could have appeared to influence the work reported in this paper.

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Author contributions

Khaled Alzoubi contributed to conceptualization, methodology, formal analysis, data collection, validation, supervision, writing, original draft preparation, review and editing. Ahmad Marei contributed to conceptualization, methodology, writing and original draft preparation. Ali Mohammad Ali Alqudah contributed to software (SPSS) review and editing. Khalid Thaher Amayreh contributed to legal review. Mohammad Issa Alzoubi contributed to writing, reviewing and editing. Ahmad Alsharu contributed to writing review and editing. All authors have read and agreed to the published version of the manuscript.

Ethical approval statement

Our institution does not require research ethics approval for reporting individual cases or case series.

Informed consent

Informed consent was obtained from all individual participants involved in the study prior to data collection

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