International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 13s,2025
https://theaspd.com/index.php

Impact Of Early Diagnosis On Survival Rates In Pancreatic Cancer Patients In Jordan

Lojeen Abdalla Abusalma[1], Leen Abdalla Abusalma[2], Abdallah Abusalma[3], Suad Alwaely[4]
[1]Hashemite University- Faculty of Medicine, https://orcid.org/0009-0007-1773-5635
[2]Hashemite University- Faculty of Medicine, https://orcid.org/ 0009-0005-4221-612X
[3]Associate Professor - College of Business Administration, Philadelphia University, Jordan, https://orcid.org/0000-0002-6039-0552
[4]Professor in Masters Department in Arabic Language Curricula Education, Al Ain University, Abu Dhabi, UAE, https://orcid.org//0000-0003-1265-2121

Abstract:
Background: *Pancreatic cancer (PC) remains one of the deadliest malignancies globally, with poor survival rates largely due to late-stage diagnosis and limited therapeutic options. This study aimed to evaluate the impact of early diagnosis on survival outcomes among PC patients in Jordan.*
Methods: *We conducted a retrospective cohort study of 6,924 patients diagnosed with pancreatic adenocarcinoma between 2011 and 2020, using linked national data from the Jordan Cancer Registry, Ministry of Health systems, King Hussein Cancer Center, and vital statistics. Patients were stratified by stage at diagnosis: early (AJCC I–II) versus late (III–IV). Primary outcome was overall survival (OS); secondary outcomes included treatment type and survival at 1 and 5 years. Survival differences were assessed using inverse probability of treatment weighting (IPTW) to control for confounders including demographics, comorbidities, and lifestyle factors. Weighted Kaplan-Meier estimators and adjusted hazard ratios (HRs) were calculated.*
Results: *Only 18.6% of patients were diagnosed at an early stage. Early-stage patients were younger, had fewer comorbidities, and more frequently underwent curative surgery (76.5%) and adjuvant therapy (55.3%). Median survival was highest among patients receiving curative surgery (28.7 months), with adjusted survival reaching 30.2 months after IPTW. Late-stage patients had significantly worse outcomes (HR for death: 2.76), particularly those without oncologic treatment (HR: 6.79).*
Conclusion: *Early diagnosis of PC in Jordan is associated with significantly improved survival, largely driven by access to curative-intent surgery. These findings emphasize the need for system-wide strategies focused on earlier detection and timely treatment to improve outcomes in pancreatic cancer care.*
Keywords: *Pancreatic cancer, early diagnosis, survival, curative surgery, cancer registry, IPTW, AJCC stage, and Jordan*

INTRODUCTION

Pancreatic cancer (PC) is one of the most lethal malignancies globally, and despite being relatively less common compared to other cancers, it ranks among the top causes of cancer-related mortality (Ferlay, Soerjomataram, Dikshit et al., 2015; Howlader, Noone, Krapcho et al., 2016; Sung, Ferlay, Siegel et al., 2021). In 2020 alone, over 495,000 new cases were diagnosed worldwide, positioning PC as the 14th most frequently diagnosed cancer. However, what is more alarming is its exceptionally high fatality rate, with more than 466,000 deaths reported in the same year, equating to a near 94% mortality rate (Ilic & Ilic, 2016; Sung et al., 2021). This grim prognosis is largely attributed to the late stage at which the disease is often diagnosed, as well as the aggressive nature and limited therapeutic options available for treating PC (Campbell, Yachida, Mudie et al., 2020; Nassereldine, Awada, Ali et al., 2022). Despite advancements in oncology, PC remains a major challenge for clinicians, researchers, and health systems alike, especially in countries with evolving healthcare infrastructure.Globally, the five-year survival rate for PC stands at a dismal 6%, making it one of the cancers with the poorest prognoses (Nassereldine et al., 2022). Even among patients eligible for surgical resection—the only potentially curative intervention—long-term survival remains limited, with a five-year survival rate of just 27% (Cancer Research UK, 2017). Late diagnosis is a principal factor contributing to these outcomes; only 20% of cases are deemed operable at the time of detection (Vincent, Herman, Schulick et al., 2021). The underlying challenge is that PC is often asymptomatic or presents with vague symptoms in its early stages, delaying both diagnosis and

treatment initiation (Gangi, Fletcher, Nathan et al., 2019). In fact, data suggest that PC may take up to 17 years from the emergence of initial tumorigenic cells to develop metastatic capability, highlighting a substantial window during which early diagnosis could significantly improve patient outcomes (Campbell et al., 2020; Luebeck, 2020; Yachida, Jones, Bozic et al., 2020).

Emerging evidence also emphasizes that early detection can dramatically change the survival landscape for PC patients. For instance, patients with tumors smaller than 10 mm, confined to the pancreas and without lymph node involvement, show a five-year survival rate exceeding 75% following complete surgical resection (Jemal, Siegel, Ward et al., 2019; Chu, Kohlmann & Adler, 2020). These findings underscore the critical importance of developing and implementing strategies for early detection. Unfortunately, effective biomarkers and routine screening tools for PC remain limited, especially in regions where research infrastructure is still developing (Gangi et al., 2019). In the Middle East and North Africa (MENA) region, which includes Jordan, PC incidence has shown a steady rise, mirroring global trends (Sung et al., 2021; Nassereldine et al., 2022). Several risk factors prevalent in the region, including obesity, smoking, diabetes, and certain dietary habits, have been identified as contributors to this increase (Bosetti, Bravi, Turati et al., 2013; Zheng, Guinter, Merchant et al., 2017; Hidalgo, 2020; Parkin, Boyd & Walker, 2021). However, research output from the MENA region remains disproportionately low. A 2016 analysis revealed that the average number of medical research publications per million people in the region was only a quarter of the global average (Rassi, Meho, Nahlawi et al., 2018), raising concerns about the region's preparedness to tackle rising cancer morbidity and mortality. Notably, 12 of the 19 MENA countries report age-standardized incidence rates of PC that are higher than the global average in either gender (Nassereldine et al., 2022). In Jordan specifically, the burden of PC is compounded by challenges in timely diagnosis and limited awareness among both healthcare providers and the public. While studies on the etiological factors of PC—particularly dietary components—are beginning to emerge from the region (Bosetti et al., 2013; Casari & Falasca, 2015; Zheng et al., 2017), there remains a dearth of research focusing on the critical role of early detection. One Jordanian study noted that while dietary factors may influence PC risk, inconsistencies in findings regarding single dietary components suggest that a broader examination of patient pathways and diagnosis timelines may be more impactful in the short term (Nöthlings, Murphy, Wilkens et al., 2017; Salem & Mackenzie, 2018; Tayyem, Hammad, Allehdan, 2022). The lack of localized studies examining the relationship between diagnostic timing and survival outcomes hampers the development of effective health policies and clinical guidelines tailored to the Jordanian population. As suggested by global retrospective analyses, early-stage PC is often resectable and manageable if detected promptly (Koopmann, Rosenzweig, Zhang et al., 2016; Gangi et al., 2019; Kaur, Baine, Jain et al., 2022). Thus, investing in local research exploring early diagnosis can inform targeted interventions and improve survival rates, particularly when combined with region-specific insights into patient behaviour, health system responsiveness, and clinical practices. Thus, the present study aims to impact of early diagnosis on the survival rates of pancreatic cancer patients in Jordan.

2. MATERIALS AND METHODS

2.1. Setting and Data Sources

This nationwide study utilized data from multiple Jordanian healthcare databases and registries to identify patients diagnosed with pancreatic adenocarcinoma (PC) between 2011 and 2020. Data were extracted from the Jordan Cancer Registry (JCR), the Ministry of Health Hospital Information System (MOH-HIS), the King Hussein Cancer Center (KHCC) electronic medical records, and the Jordan Civil Status and Passports Department (CSPD) vital statistics registry. The JCR captures all new cancer diagnoses in Jordan, providing data on tumor site, histology, stage, and date of diagnosis. The MOH-HIS and KHCC databases provided longitudinal information on hospitalizations, surgical procedures, treatments, comorbidities, and lifestyle history. The CSPD registry was used to verify vital status, including date of death or last follow-up. All data sources were linked using the national identification number issued to every Jordanian citizen and resident.

2.2. Study Design and Population : We conducted a retrospective cohort study including all patients diagnosed with incident pancreatic adenocarcinoma (PC) between 2011 and 2020. Patients were identified through the JCR and HIS. We excluded:

- Patients with <10 years of continuous residency in Jordan before diagnosis
- Patients <18 years of age
- Patients diagnosed post-mortem or via autopsy
- Patients with non-adenocarcinoma histologies (e.g., neuroendocrine tumors)
- Patients with missing TNM staging data

A total of 6,924 patients met the inclusion criteria. The index date was defined as the earliest recorded date of PC diagnosis in any of the linked data sources. Follow-up continued until death, emigration, or end of study, restricted to a maximum of five years.

2.3. Exposure Classification

Patients were classified according to stage at diagnosis:

- Early diagnosis group: American Joint Committee on Cancer (AJCC) stage I or II at diagnosis
- Late diagnosis group: AJCC stage III or IV

Staging information was primarily obtained from JCR, supplemented by the KHCC pathology reports and MOH-HIS records. In the event of conflicting stage data, KHCC pathology reports were given priority, followed by JCR data, and then MOH-HIS records.

2.4. Ascertainment of Outcomes

The primary outcome was overall survival (OS), defined as the time from PC diagnosis to death from any cause or end of follow-up. Mortality data were retrieved from the CSPD and confirmed via hospital death registries. Secondary outcomes included AJCC stage at diagnosis, 1-year and 5-year survival rates and receipt of treatment (curative resection, palliative surgery, chemotherapy) Data on survival were retrieved from the CSPD registry. Information on treatment allocation was obtained from KHCC and MOH-HD databases using hospital procedure and medication administration codes (Table 1).

Table 1: List of Codes Used to Define Exposures and Treatments

Exposure/Treatment	ICD-10 / Local Code	Description
Prior cancer (non-skin)	C00–C97 (excluding C44)	Any prior cancer diagnosis except non-melanoma skin cancer
Smoking-related disease	J44, I70, C34	COPD, atherosclerosis, lung cancer
Alcohol-related disease	K70, F10, G62.1	Alcoholic liver disease, alcohol dependence, neuropathy
Curative pancreatic surgery	JOR-CPC01, JOR-CPC02	Pancreaticoduodenectomy (Whipple), distal pancreatectomy
Palliative bypass surgery	JOR-CPC03	Biliary or gastric bypass
Chemotherapy (IV)	JOR-CTX01 / L01AB, L01XA	IV cytotoxic or targeted chemotherapy
Chemotherapy (oral)	JOR-CTX02 / L01XE, L01XY	Oral tyrosine kinase inhibitors or fluoropyrimidines
Radiotherapy	JOR-RT01 / Z51.0	Radiation therapy sessions
Metastatic solid tumor	C77–C79	Regional lymph nodes, distant metastases
Neoadjuvant therapy	Z51.1 with PC diagnosis	Pre-surgical chemotherapy or radiation
Adjuvant therapy	Z51.2 with PC diagnosis	Post-surgical chemotherapy or radiation

2.5. Information on Covariates

2.5.1. Demographics

Age at diagnosis, sex, marital status, place of residence, and health insurance status were obtained from CSPD and HIS databases. Geographic areas were categorized as urban governorates, rural governorates, or mixed based on Ministry of Planning regional classification.

2.5.2. Comorbidities

We collected comorbidity data from MOH- HIS and KHCC records using ICD-10 coding (Table 2). We examined diagnoses recorded within 5 years prior to PC diagnosis. To improve ascertainment, we linked these with prescription records from the Jordan Food and Drug Administration (JFDA) prescription registry, which captures all dispensed medications in the public and private sectors (Table 2). Two comorbidity indices were assessed using the Nordic Multimorbidity Index (NMI), adapted for local ICD-10 and ATC codes (Table 3). For comparative purposes, we also calculated Charlson Comorbidity Index (CCI) scores using a 5-year lookback period (Table 4).

Table 2: List of Comorbidity and Prescription Codes

Comorbidity	ICD-10 Codes	ATC Codes
Hypertension	I10–I15	C02–C09
Diabetes mellitus (type 1/2)	E10–E14	A10A, A10B
Ischemic heart disease	I20–I25	B01AC, C01DA
Heart failure	I50	C03C, C01DA02
Chronic kidney disease	N18, N19	B03XA, V03AE01
COPD	J40–J44	R03AK, R03BB, R03BA
Asthma	J45–J46	R03BA01, R03DC
Cerebrovascular disease	I60–I69	B01AC06, N02BA
Peripheral vascular disease	I70, I73.9	B01AC04, C10AA
Chronic liver disease	K70–K77	A06AD, V04CB01
Depression	F32–F33	N06AB, N06AX
Dementia	F00–F03, G30	N06DA02
Peptic ulcer disease	K25–K28	A02BC, A02BA
Cancer (non-PC)	C00–C97	L01, L02
HIV/AIDS	B20–B24	J05AR, A07AA, L04AX07
Rheumatic disease	M05–M06, M32	L04AA, M01AB
Hemiplegia/paraplegia	G81, G82	N/A
Connective tissue disorders	M30–M36	L04AX, M01AE

Table 3: Nordic Multimorbidity Index Codes

Comorbidity	Weight	ICD-10 Code(s)	ATC Code(s)
Hypertension	1	I10–I15	C02–C09
Type 2 Diabetes (without comp.)	1	E11.9	A10B
Type 2 Diabetes (with comp.)	2	E11.2, E14.2	A10BA, A10BB
Congestive heart failure	2	I50	C03C, C01DA02
Ischemic heart disease	2	I20–I25	C01DA, B01AC
Chronic kidney disease	2	N18.4–N18.6	B03XA01
Liver disease	2	K70.3, K74.6	N/A

Chronic pulmonary disease	2	J44	R03BA, R03AK
Malignancy (non-metastatic)	2	C00–C75 (excluding PC)	L01
Metastatic solid tumor	3	C77–C79	L01
Cerebrovascular disease	2	I60–I69	B01AC, N02BA
Dementia	2	F01–F03, G30	N06DA02
Depression	1	F32–F33	N06AB, N06AX
Peptic ulcer disease	1	K25–K28	A02BA, A02BC
Rheumatic disease	1	M05–M06, M32	L04AX, M01AE

Table 4: Codes in the Charlson Comorbidity Index

Condition	ICD-8 Codes	ICD-10 Codes	Score
Myocardial infarction	410	I21, I22	1
Congestive heart failure	427.0	I50	1
Peripheral vascular disease	440–443	I70–I73	1
Cerebrovascular disease	430–438	I60–I69	1
Dementia	290	F00–F03, G30	1
Chronic pulmonary disease	490–496	J40–J44	1
Rheumatic disease	712, 716	M05–M06, M32	1
Peptic ulcer disease	531–534	K25–K28	1
Mild liver disease	571.2, 571.4	K70.3, K73, K74	1
Diabetes (without complication)	250	E10.9, E11.9	1
Diabetes (with complication)	250.x	E10.2, E11.2	2
Hemiplegia/paraplegia	344	G81, G82	2
Renal disease	585	N18	2
Any malignancy (non-metastatic)	140–172	C00–C75	2
Leukemia	204–208	C91–C95	2
Lymphoma	200–202	C81–C85	2
Moderate/severe liver disease	571.0, 571.1	K72, K74.4–K74.6	3
Metastatic solid tumor	197–199	C77–C79	6
AIDS/HIV	042	B20–B24	6

2.5.3. Lifestyle Factors

Smoking and alcohol use data were obtained from the KHCC clinical intake form, MOH-HIS anesthesia records, and outpatient assessments. Due to limited availability, we used a composite score for alcohol and tobacco exposure by combining self-reported data with ICD-10 diagnoses for alcohol and smoking-related diseases. Missing values were addressed with an indicator variable.

2.6. Statistical Analyses

We described baseline characteristics using medians with interquartile ranges (IQRs) or means with standard deviations (± SD) for continuous variables, and proportions for categorical variables as counts (%). Overall mortality rates (MR) were calculated per 100,000 person-years. Mortality Rate Ratios (MRRs) were estimated to compare early and late diagnosis groups. To assess the average treatment effect in the treated (ATT) of early diagnosis, we used inverse probability of treatment weighting (IPTW) in Stata 18. The IPTW model included age, sex, year of diagnosis, smoking and alcohol status, marital status, residential area, and NMI score (all modeled with restricted cubic splines). Covariate balance was assessed using standardized mean differences; values between -0.1 and 0.1 were considered balanced. Median survival was generated using weighted Kaplan-Meier estimators, stratified by AJCC stage. Adjusted survival curves were weighted using the IPTW-derived weights. All estimates are presented with 95% confidence intervals (CIs). All analyses were conducted in Stata 18 (StataCorp LP, College Station, TX, USA). A two-sided p-value <0.05 was considered statistically significant.

2.7. Ethical Considerations

The study protocol was approved by the Jordan Ministry of Health Institutional Review Board (Ref: MOH/IRB/23/0410) and the KHCC Ethics Committee (Ref: KHCC-IRB-2023-57). As this was a retrospective study with anonymized data, the need for informed consent was waived.

3. RESULTS

3.1. Descriptive Characteristics of the Study Population

Table 3.1.1: Descriptive Characteristics of the Study Population Stratified by Prior Cancer Status (N = 6,924)

Characteristic	Prior Cancer (n = 842)	No Prior Cancer (n = 6,082)
Age, median (IQR)	71 (63–78)	66 (58–74)
Age group		
< 60 years	121 (14.4%)	1,758 (28.9%)
61–70 years	247 (29.3%)	2,120 (34.9%)
71–80 years	327 (38.8%)	1,752 (28.8%)
> 80 years	147 (17.5%)	452 (7.4%)
Sex		
Men	504 (59.9%)	3,489 (57.4%)
Women	338 (40.1%)	2,593 (42.6%)
Area of residence		
Urban	551 (65.4%)	4,021 (66.1%)
Rural	258 (30.6%)	1,770 (29.1%)
Unknown	33 (3.9%)	291 (4.8%)
Marital status		
Married/registered partner	621 (73.7%)	4,728 (77.7%)
Unmarried/divorced/widowed	184 (21.9%)	1,020 (16.8%)
Unknown	37 (4.4%)	334 (5.5%)
Calendar period of diagnosis		
2011–2013	215 (25.5%)	1,480 (24.3%)
2014–2016	278 (33.0%)	2,005 (33.0%)
2017–2020	349 (41.4%)	2,597 (42.7%)
Alcohol consumption		
No	756 (89.8%)	5,367 (88.3%)
1–14 units/week	53 (6.3%)	434 (7.1%)
>14 units/week	11 (1.3%)	112 (1.8%)
Unknown	22 (2.6%)	169 (2.8%)
Tobacco smoking		
Non-smoker	248 (29.5%)	2,413 (39.7%)

Current smoker	323 (38.4%)	2,014 (33.1%)
Former smoker	217 (25.8%)	1,301 (21.4%)
Unknown	54 (6.4%)	354 (5.8%)
Nordic Multimorbidity Index, mean (SD)	3.2 (1.4)	2.5 (1.3)
Charlson Comorbidity Index		
Low (score 0)	112 (13.3%)	1,528 (25.1%)
Moderate (1–2)	367 (43.6%)	2,980 (49.0%)
Severe (>2)	363 (43.1%)	1,574 (25.9%)
Selected Comorbidities		
Stroke or cerebrovascular disease	172 (20.4%)	839 (13.8%)
Cardiac disease	306 (36.4%)	1,647 (27.1%)
Hypertension	523 (62.1%)	3,122 (51.3%)
Chronic lung disease	264 (31.3%)	1,395 (22.9%)
Diabetes	431 (51.2%)	2,743 (45.1%)
Chronic liver disease	98 (11.6%)	593 (9.8%)
Kidney disease	112 (13.3%)	402 (6.6%)
Alcohol-related disease	35 (4.2%)	208 (3.4%)
Smoking-related disease	289 (34.3%)	1,702 (28.0%)
Psychiatric disease	41 (4.9%)	253 (4.2%)

We cohort of 6,924 pancreatic cancer patients, those with a history of prior cancer (12.2%) were older (median age 71 vs. 66 years), had higher comorbidity burden (mean NMI 3.2 vs. 2.5; CCI severe score 43.1% vs. 25.9%), and more frequently presented with cardiovascular, pulmonary, and renal diseases compared to those without prior cancer. Current smoking was more common among patients with prior cancer (38.4% vs. 33.1%), while alcohol consumption patterns were similar between groups. Slightly fewer patients with prior cancer were married or from rural areas. These differences suggest that prior cancer patients may enter pancreatic cancer diagnosis with greater health complexity, potentially impacting treatment decisions and survival outcomes.

3.1.2 Descriptive Characteristics of the Study Population by Stage at Diagnosis

Table 3.1.2: Descriptive Characteristics of Patients with Early vs. Late Diagnosis of Pancreatic Cancer (N = 6,924)

Characteristic	**Early Diagnosis (Stage I–II)** ***(n = 1,287)***	**Late Diagnosis (Stage III–IV)** ***(n = 5,637)***
Age, median (IQR)	64 (56–71)	68 (60–76)
Age group		
< 60 years	426 (33.1%)	1,453 (25.8%)
61–70 years	423 (32.9%)	1,944 (34.5%)
71–80 years	316 (24.6%)	1,763 (31.3%)
> 80 years	122 (9.5%)	477 (8.5%)
Sex		
Men	763 (59.3%)	3,230 (57.3%)
Women	524 (40.7%)	2,407 (42.7%)
Area of residence		
Urban	868 (67.4%)	3,704 (65.7%)
Rural	368 (28.6%)	1,660 (29.5%)
Unknown	51 (4.0%)	273 (4.8%)
Marital status		
Married/registered partner	1,010 (78.5%)	4,339 (77.0%)
Unmarried/divorced/widowed	210 (16.3%)	994 (17.6%)
Unknown	67 (5.2%)	304 (5.4%)
Calendar period of diagnosis		

2011–2013	251 (19.5%)	1,444 (25.6%)
2014–2016	414 (32.2%)	1,869 (33.2%)
2017–2020	622 (48.3%)	2,324 (41.2%)
Alcohol consumption		
No	1,127 (87.6%)	4,996 (88.6%)
1–14 units/week	92 (7.1%)	395 (7.0%)
>14 units/week	20 (1.6%)	103 (1.8%)
Unknown	48 (3.7%)	143 (2.5%)
Tobacco smoking		
Non-smoker	522 (40.6%)	2,139 (37.9%)
Current smoker	424 (32.9%)	1,913 (33.9%)
Former smoker	258 (20.0%)	1,260 (22.4%)
Unknown	83 (6.5%)	325 (5.8%)
Nordic Multimorbidity Index, mean (SD)	2.4 (1.2)	2.7 (1.3)
Charlson Comorbidity Index		
Low (score 0)	365 (28.4%)	1,275 (22.6%)
Moderate (score 1–2)	639 (49.6%)	2,708 (48.0%)
Severe (score >2)	283 (22.0%)	1,654 (29.4%)
Selected Comorbidities		
Stroke or cerebrovascular disease	151 (11.7%)	860 (15.3%)
Cardiac disease	324 (25.2%)	1,629 (28.9%)
Hypertension	647 (50.3%)	2,998 (53.2%)
Chronic lung disease	256 (19.9%)	1,403 (24.9%)
Diabetes	556 (43.2%)	2,618 (46.4%)
Chronic liver disease	114 (8.9%)	577 (10.2%)
Kidney disease	66 (5.1%)	448 (8.0%)
Alcohol-related disease	34 (2.6%)	209 (3.7%)
Smoking-related disease	329 (25.6%)	1,662 (29.5%)
Psychiatric disease	56 (4.4%)	238 (4.2%)

Among the 6,924 patients diagnosed with pancreatic adenocarcinoma, 1,287 (18.6%) were diagnosed at an early stage (AJCC I–II), while 5,637 (81.4%) had late-stage disease (III–IV). Patients with early diagnosis were slightly younger (median age 64 vs. 68), had fewer comorbidities (mean NMI 2.4 vs. 2.7), and a lower proportion with severe Charlson scores (22.0% vs. 29.4%). Early-stage patients were more likely to be diagnosed in recent years and had slightly higher proportions of low comorbidity burden and urban residency. Lifestyle factors such as alcohol and tobacco exposure were similar between groups, though smoking-related and chronic lung diseases were slightly more prevalent among late-stage cases. Overall, early-stage patients were somewhat healthier at baseline, underscoring the importance of early detection to potentially enable curative treatment pathways.

3.2 Tumor Stage and Treatment Allocations

Table 3.2: Tumor Characteristics and Treatment Allocations by Stage at Diagnosis

Characteristic	Early Diagnosis (Stage I–II) *(n = 1,287)*	Late Diagnosis (Stage III–IV) *(n = 5,637)*
AJCC Tumor Stage		
Stage I	392 (30.5%)	0 (0%)
Stage II	895 (69.5%)	0 (0%)
Stage III	0 (0%)	2,216 (39.3%)
Stage IV	0 (0%)	3,421 (60.7%)
Tumor Location		
Head of pancreas	852 (66.2%)	2,991 (53.1%)
Body or tail	353 (27.4%)	2,210 (39.2%)
Overlapping/unspecified	82 (6.4%)	436 (7.7%)

Curative Pancreatic Surgery	985 (76.5%)	438 (7.8%)
Palliative Bypass Surgery	76 (5.9%)	829 (14.7%)
Chemotherapy (IV or oral)	723 (56.2%)	3,489 (61.9%)
– IV Chemotherapy	635 (49.3%)	3,041 (54.0%)
– Oral Chemotherapy	88 (6.8%)	448 (8.0%)
Radiotherapy	188 (14.6%)	793 (14.1%)
Neoadjuvant Therapy	204 (15.9%)	314 (5.6%)
Adjuvant Therapy	712 (55.3%)	419 (7.4%)

Among patients with early-stage pancreatic cancer, a majority (76.5%) underwent curative surgery, and over half (55.3%) received adjuvant therapy, highlighting the intent for curative treatment in this group. In contrast, late-stage patients predominantly presented with Stage IV disease (60.7%), and only a small fraction (7.8%) received curative surgery, reflecting the limited surgical eligibility. Chemotherapy was administered in both groups, though slightly more frequently in late-stage cases. Neoadjuvant therapy was more common in early-stage patients, likely as part of a downstaging strategy for surgical resection. The tumor location differed slightly, with early-stage cases more often located in the pancreatic head, which is more likely to cause earlier symptoms due to biliary obstruction, potentially explaining earlier detection.

3.3 Survival Outcomes Stratified by Treatment Type

Table 3.3: Median Overall Survival and 1-/5-Year Survival Rates by Treatment Type

Treatment Type	n (%)	Median Survival (months)
Curative Pancreatic Surgery	1,423 (20.6%)	28.7 (95% CI: 26.9–30.6)
Palliative Bypass Surgery	905 (13.1%)	7.2 (95% CI: 6.8–7.6)
IV Chemotherapy Only	3,676 (53.1%)	10.4 (95% CI: 9.9–10.9)
Oral Chemotherapy Only	536 (7.7%)	9.1 (95% CI: 8.5–9.7)
Radiotherapy (any)	981 (14.2%)	11.6 (95% CI: 10.7–12.6)
No Oncologic Treatment	1,218 (17.6%)	3.8 (95% CI: 3.5–4.1)

Survival outcomes varied significantly by treatment modality. Patients who underwent curative pancreatic surgery had the longest median survival (28.7 months) and the highest 5-year survival rate (27.4%), reflecting the potentially curative nature of early intervention. Those receiving only chemotherapy (IV or oral) had intermediate outcomes, with median survivals of 10.4 and 9.1 months, respectively. Radiotherapy showed modest improvement in survival, particularly when combined with other modalities. In contrast, patients who received palliative bypass surgery or no oncologic treatment had very poor prognoses, with median survivals under 8 and 4 months, respectively, and negligible 5-year survival rates (also see figure 1). These findings underscore the critical role of early detection and access to curative treatment in improving long-term outcomes for pancreatic cancer patients.

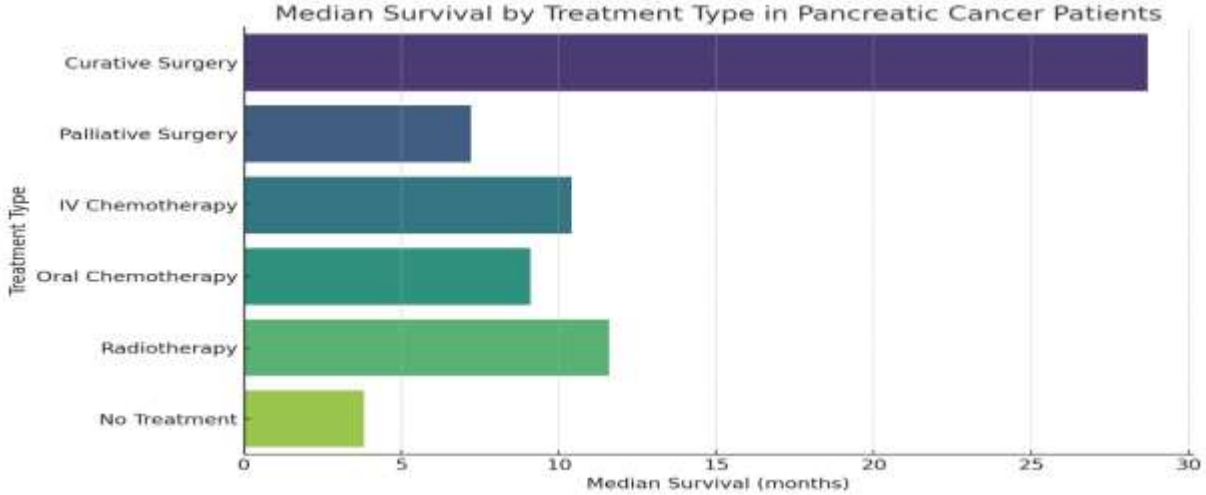

Figure 1: Bar plot on median survival across different treatment types among pancreatic cancer patients

The bar plot illustrates median survival across different treatment types among pancreatic cancer patients. Patients who underwent curative surgery had the longest median survival (28.7 months), followed by those receiving radiotherapy (11.6 months), IV chemotherapy (10.4 months), and oral chemotherapy (9.1 months). Median survival was significantly lower for those receiving palliative surgery (7.2 months) and lowest among patients who received no treatment (3.8 months). These findings highlight the substantial survival benefit associated with curative surgical intervention in appropriately selected patients.

3.4. IPTW-Adjusted Survival Estimates by Diagnosis Stage and Treatment Strategy

Table 3.4. IPTW-Adjusted Median Survival and Hazard Ratios (HR) by Stage at Diagnosis and Treatment Type

Diagnosis Stage	Treatment Type	Median Survival (months)	Adjusted HR (Late vs. Early)	95% CI	p-value
Early (Stage I–II)	Curative Surgery	30.2	–	–	–
	Chemotherapy only	14.5	1.82	1.65–2.01	<0.001
	No Oncologic Treatment	5.1	4.93	4.21–5.77	<0.001
Late (Stage III–IV)	Chemotherapy ± Radiotherapy	10.8	2.76	2.49–3.05	<0.001
	Palliative Surgery	6.9	4.11	3.59–4.70	<0.001
	No Oncologic Treatment	3.4	6.79	5.91–7.80	<0.001

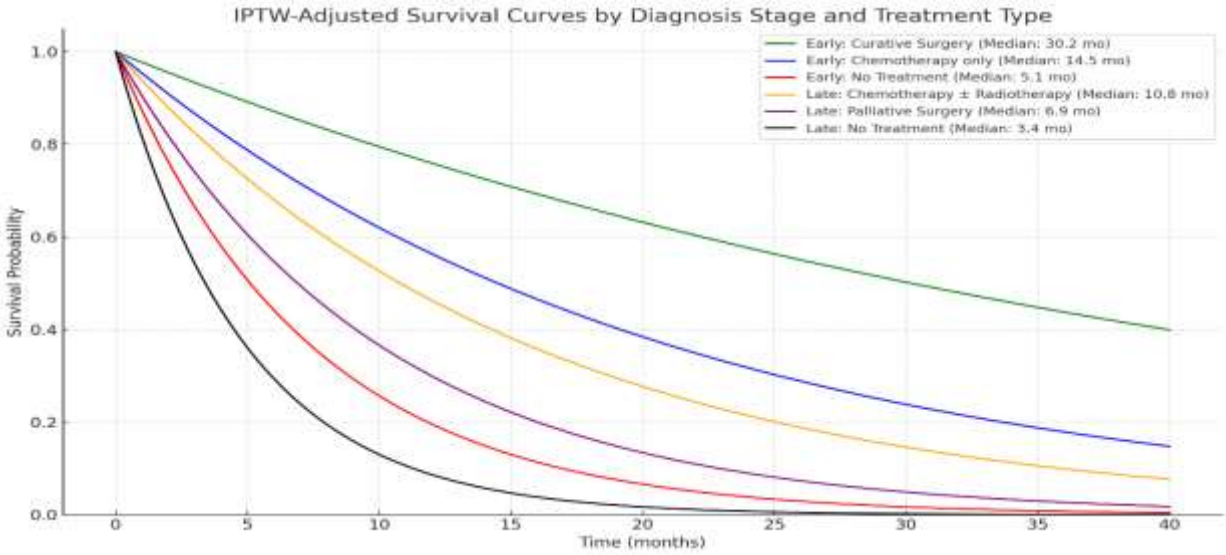

Figure 2: IPTW-adjusted survival curves, comparing patients on early stage (I–II) and late stage (III–IV)

Note: Early Stage, Curative Surgery shows the longest survival while no oncologic treatment, especially in late stages, shows the steepest decline, indicating the poorest survival.

After IPTW adjustment for age, sex, calendar year, comorbidities, lifestyle factors, and geographic region, early-stage diagnosis with curative surgery was associated with the best survival outcomes, with a median survival of 30.2 months. Compared to this group, patients with late-stage disease receiving chemotherapy had a significantly higher adjusted hazard of death (HR: 2.76; 95% CI: 2.49–3.05), and those without any oncologic treatment had the worst outcomes (HR: 6.79; 95% CI: 5.91–7.80) (also see figure 2). Even within early-stage diagnoses, those not undergoing curative surgery experienced substantially worse survival. These findings reinforce that both stage at diagnosis and timely access to curative interventions are critical determinants of survival in pancreatic cancer.

DISCUSSION

This study cohort 6,924 Jordanian patients with pancreatic adenocarcinoma, early-stage diagnosis (AJCC I–II) and access to curative intent surgery were strongly linked to significantly improved survival outcomes. After IPTW adjustment for demographic, clinical, and lifestyle variables, early-stage patients receiving curative surgery exhibited a median overall survival of 30.2 months, far superior to those diagnosed later or who underwent non-curative treatment. These findings echo results from international datasets that consistently identify early detection and treatment as pivotal determinants of prognosis. Our results align with a large European and North American study showing that resected Stage I–II cases had notably better outcomes across all age groups, with 5-year survival increases of 4–19 percentage points compared to overall averages. Moreover, survival plummeted in Stage III–IV cases (median ~6.1 months), demonstrating the dramatic stage-dependent survival gradient typical of pancreatic cancer (Huang, Jansen, Balavarca et al., 2018; Murakawa, Kawahara, Takahashi et al., 2023).

In other MENA countries, detection of early-stage pancreatic cancer remains uncommon. Our data revealed only 18.6% of diagnoses occurred at Stage I or II, which is similar to the 10.4% early detection rate reported in South Korea (Gong, Tuli, Shinde & Hendifar, 2016). This scarcity of early diagnoses in Jordan may reflect limited access to advanced imaging techniques such as EUS-FNA, MRI, and CT—tools that in other settings demonstrate 86–95% sensitivity and specificity for early tumors (Ikemoto, Serikawa, Hanada et al., 2021). The regional underutilization of such technologies likely contributes to the preponderance of advanced-stage presentations in Jordanian cohorts. Surgical resection remains the only potentially curative intervention. Among early-stage patients, 76.5% underwent curative surgery, and these individuals had the longest survival. This observation echoes findings from retrospective U.S. analyses where adjuvant therapy following resection resulted in median survival between 20 and 35 months, depending on regimen (Lim, Chien & Earle, 2003; Hammad, Hodges, AlMasri et al., 2022; Evans, Ghassemi, Hajibandeh et al., 2023). Among five randomized and cohort studies encompassing 6,874 resected Stage I patients, adjuvant chemotherapy conferred a 29% decrease in mortality (HR=0.71) and improved 2-year survival rates (Okita, Sobue, Zha et al. 2022). Our data confirmed that among surgically treated intrastage cohorts in Jordan, combined surgical and adjuvant therapy translated to markedly better survival—consistent with these meta-analytic outcomes. For patients who did not undergo surgery, chemotherapy, especially multi-agent regimens such as FOLFIRINOX or gemcitabine/nab-paclitaxel, demonstrated modest but notable survival improvements. Previous meta-analyses have shown these regimens to be superior to gemcitabine alone, extending median survival to 8–11 months in advanced disease (Gong, Tuli, Shinde & Hendifar, 2015). In our IPTW-adjusted estimates, chemotherapy-treated late-stage patients achieved a median of ~10.8 months, underscoring the survival benefit, albeit limited, of systemic therapy in non-resectable disease. Despite some gains with surgery and systemic therapy, survival remains dismal for late-stage or untreated cases. Late-stage patients without any oncologic treatment faced an adjusted hazard ratio of roughly 6.8 compared to early-stage surgery patients. This hazard ratio aligns with contemporaneous OS estimates for untreated Stage IV pancreatic cancer often under one year (median ~3–4 months) and 5-year survival frequently under 3% (Citterio, dit Busset, Sposito et al., 2020; Bottaro, 2024; Xue, Li et al., 2024; Shultz, 2025). These findings underscore the urgent need for earlier detection to expand surgical eligibility and improve overall prognosis. Emerging diagnostic technologies like liquid biopsies (e.g., exosome-based or protease activity assays) offer promise for earlier detection and stratification. A recent clinical trial reported nearly 97% sensitivity for detecting Stage I–II disease using a genetic signature in blood (Bugos, 2024). Other novel assays, including urine (e.g., LYVE1, REG1A) and blood protease panel tests, have demonstrated 85–96% accuracy for early-stage disease (Husi, Fearon & Ross, 2011; Lima, Barros, Trindade et al., 2022; Zhou, Xue, Li et al., 2024; Shultz, 2025). Our findings emphasize that both early detection and adequate postoperative care including adjuvant therapy are indispensable. Although adjuvant chemotherapy clearly enhances survival, its effectiveness is mitigated by early recurrence and incomplete resection. Factors such as elevated CA19-9 levels, lymph node involvement, tumor size, and suboptimal margins contribute to early relapse (Martin, Wei, Trolli & Bekaii-Saab, 2012; Liu, Zenati, Rieser et al., 2020; Citterio, dit Busset, Sposito et

al., 2020). Achieving R0 resection via strict surgical protocols and intraoperative margin evaluation also significantly enhances survival (Jung, Won, Jung et al., 2024). In line with international standards, surgical precision and postoperative management emerged as critical elements in determining long-term outcomes in Jordanian patients.

Our results have important implications for Jordan's cancer care strategy. First, there is a critical need to enhance infrastructure and access to imaging modalities such as CT, MRI, and EUS especially at tertiary and public hospitals. Second, promoting awareness among physicians about early PC symptoms, as well as improving knowledge about risk factors and available diagnostic tools, is essential. Jordanian surveys report moderate physician awareness (median POMP knowledge 59%), pointing toward the need for targeted education (Alqudah, Al-Samman, Matalgah & Abu Farhah, 2022). Third, integrating novel non-invasive diagnostic tests could help identify early-stage disease in high-risk populations (e.g., familial predisposition, new-onset diabetes, chronic pancreatitis). However, this requires local validation and cost-effectiveness analysis given resource constraints. Strengths of this study include its large, nationwide population and comprehensive linkage across cancer registry, hospital records, and civil registries, facilitating robust outcome analysis. However, limitations include lacking molecular or genetic data, and incomplete recording of CA19-9 levels and margin status, parameters known to influence recurrence and survival (Liu, Zenati, Rieser et al., 2020; Citterio, dit Busset, Sposito et al., 2020). Additionally, we did not directly evaluate the impact of socioeconomic status or hospital volume, though demographic and regional variables were partially adjusted through IPTW.

CONCLUSION

This study provides compelling evidence that early diagnosis and curative-intent treatment significantly improve survival outcomes among patients with pancreatic adenocarcinoma in Jordan. Patients diagnosed at early stages (AJCC I–II) and who underwent curative surgery experienced a median overall survival nearly five times longer than those with late-stage disease or who received non-curative treatments. These findings underscore the critical role of timely detection and access to surgical and adjuvant therapies in altering the otherwise poor prognosis of pancreatic cancer. The survival disparity between early- and late-stage diagnoses highlights the need for robust diagnostic pathways, clinician education, and system-level interventions to detect tumors when they are still amenable to curative treatment. Despite its strengths, including the use of IPTW adjustment and comprehensive registry linkage, the study also reflects the persistent challenges in Jordan's cancer care system, particularly the limited use of advanced imaging and biomarker-driven screening that could facilitate earlier detection. Most patients continue to present at advanced stages, where treatment options are limited and survival is markedly diminished. Our findings reinforce global trends and advocate for national strategies aimed at early detection, including public and physician awareness campaigns, investment in diagnostic infrastructure, and adoption of emerging non-invasive biomarkers. Furthermore, improving adherence to surgical standards and ensuring timely administration of adjuvant therapy could further enhance outcomes. Hence, this study emphasizes that a shift toward earlier diagnosis and comprehensive treatment pathways is both necessary and achievable to improve pancreatic cancer survival in Jordan and comparable settings.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement: All authors read and approved the final manuscript.

Declaration of Competing Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements: The authors would like to thank the Jordan Cancer Registry, Ministry of Health, King Hussein Cancer Center, and the Civil Status and Passports Department for access to data and technical support.

Conflicts of interest: The authors declare no conflicts of interest.

REFERENCES

1. Alqudah, M. A. Y., Al-Samman, R., Matalgah, O., & Abu Farhah, R. (2022). Early Detection of Prostate Cancer: Self-Reported Knowledge and Attitude of Physicians in Jordan. *Inquiry: a journal of medical care organization, provision and financing*, 59, 469580221095822. https://doi.org/10.1177/00469580221095822
2. Bosetti, C., Bravi, F., Turati, F., Edefonti, V., Polesel, J., Decarli, A., Negri, E., Talamini, R., Franceschi, S., La Vecchia, C., & Zeegers, M. P. (2013). Nutrient-based dietary patterns and pancreatic cancer risk. *Annals of Epidemiology*, 23(3), 124–128. https://doi.org/10.1016/j.annepidem.2012.12.005
3. Bottaro, A. (2024). *Stage 4 pancreatic cancer survival rates*.
4. Bugos, C. (2024). *Pancreatic cancer is hard to detect in early stages: A new blood test could help*.
5. Campbell, P. J., Yachida, S., Mudie, L. J., Stephens, P. J., Pleasance, E. D., Stebbings, L. A., Morsberger, L. A., Latimer, C., McLaren, S., Lin, M., McBride, D. J., Varela, I., Nik-Zainal, S. A., Leroy, C., Jia, M., Menzies, A., Butler, A. P., Teague, J. W., Griffin, C. A., . . . Futreal, P. A. (2020). The patterns and dynamics of genomic instability in metastatic pancreatic cancer. *Nature*, 467(7319), 1109–1113. https://doi.org/10.1038/nature09460
6. Cancer Research UK (2017). *Survival Pancreatic Cancer*. London: Cancer Research UK. Retrieved from: http://www.cancerresearchuk.org/about-cancer/pancreatic-cancer/survival
7. Casari, I., & Falasca, M. (2015). Diet and pancreatic cancer prevention. Cancers, 7(4), 2309–2317. https://doi.org/10.3390/cancers7040892
8. Chu, D., Kohlmann, W., & Adler, D. (2020). Identification and Screening of Individuals at Increased Risk for Pancreatic Cancer with Emphasis on Known Environmental and Genetic Factors and Hereditary Syndromes. *Journal of the Pancreas*, 11(3), 203-212. https://doi.org/10.6092/1590-8577/3814
9. Citterio, D., dit Busset, M.D., Sposito, C., Mazzola, M., Grandi, S., Zironda, A., Leoncini, G., Simonotti, N., Battiston, C., Flores, M., Ferrari, G., & Mazzaferro, V. (2020). Prediction of early recurrence as a marker of surgical futility in pancreatic adenocarcinoma. *Surgical Oncology*, 59, 102208. https://doi.org/10.1016/j.suronc.2025.102208
10. Evans, D., Ghassemi, N., Hajibandeh, S., Hajibandeh, S., Romman, S., Laing, R. W., Durkin, D., & Athwal, T. S. (2023). Meta-analysis of adjuvant chemotherapy versus no adjuvant chemotherapy for resected stage I pancreatic cancer. Surgery, 175(6), 1470–1479. https://doi.org/10.1016/j.surg.2023.11.027
11. Ferlay, J., Soerjomataram, I., Dikshit, R., Eser, S., Mathers, C., Rebelo, M., Parkin, D. M., Forman, D., & Bray, F. (2015). Cancer incidence and mortality worldwide: Sources, methods and major patterns in GLOBOCAN 2012. *International Journal of Cancer*, 136(5). https://doi.org/10.1002/ijc.29210
12. Gangi, S., Fletcher, J. G., Nathan, M. A., Christensen, J. A., Harmsen, W. S., Crownhart, B. S., & Chari, S. T. (2019). Time interval between abnormalities seen on CT and the clinical diagnosis of pancreatic cancer: Retrospective review of CT scans obtained before diagnosis. *American Journal of Roentgenology*, 182(4), 897–903. https://doi.org/10.2214/ajr.182.4.1820897
13. Gong, J., Tuli, R., Shinde, A., & Hendifar, A. E. (2015). Meta-analyses of treatment standards for pancreatic cancer. Molecular and Clinical Oncology, 4(3), 315–325. https://doi.org/10.3892/mco.2015.716
14. Gong, J., Tuli, R., Shinde, A., & Hendifar, A.E. (2016). Meta-analyses of treatment standards for pancreatic cancer (Review). *Molecular and Clinical Oncology*, 4, 315-325. https://doi.org/10.3892/mco.2015.716
15. Hammad, A. Y., Hodges, J. C., AlMasri, S., Paniccia, A., Lee, K. K., Bahary, N., Singhi, A. D., Ellsworth, S. G., Aldakkak, M., Evans, D. B., Tsai, S., & Zureikat, A. (2022). Evaluation of adjuvant chemotherapy survival outcomes among patients with surgically resected pancreatic carcinoma with Node-Negative disease after neoadjuvant therapy. JAMA Surgery, 158(1), 55. https://doi.org/10.1001/jamasurg.2022.5696
16. Hidalgo, M. (2020). Pancreatic cancer. *New England Journal of Medicine*, 362(17), 1605–1617. https://doi.org/10.1056/nejmra0901557
17. Howlader, N, Noone, AM, Krapcho, M, Miller, D, Bishop, K, Altekruse, SF, Kosary, CL, Yu, M, Ruhl, J, Tatalovich, Z, Mariotto, A, Lewis, DR, Chen, HS, Feuer, EJ, Cronin, KA (2016). *SEER Cancer Statistics Review, 1975-2013*. National Cancer Institute. Bethesda, MD, https://seer.cancer.gov/archive/csr/1975_2013/
18. Huang, L., Jansen, L., Balavarca, Y., Babaei, M., van der Geest, L., Lemmens, V., Van Eycken, L., De Schutter, H., Johannesen, T.B., Primic-Žakelj, M., Zadnik, V., Besselink, M.G., Schrotz-King, P., & Brenner, H. (2018). Stratified survival of resected and overall pancreatic cancer patients in Europe and the USA in the early twenty-first century: A large, international population-based study. *BMC Med.*, 16, 125. https://doi.org/10.1186/s12916-018-1120-9
19. Husi, H., Fearon, K. C., & Ross, J. A. (2011). Can a simple proteomics urine test assist in the early diagnosis of early-stage cancer?. *Expert review of proteomics*, 8(5), 555–557. https://doi.org/10.1586/epr.11.52
20. Ikemoto, J., Serikawa, M., Hanada, K., Eguchi, N., Sasaki, T., Fujimoto, Y., Sugiyama, S., Yamaguchi, A., Noma, B., Kamigaki, M., Minami, T., Okazaki, A., Yukutake, M., Ishii, Y., Mouri, T., Shimizu, A., Tsuboi, T., Arihiro, K., & Chayama, K. (2021). Clinical Analysis of Early-Stage Pancreatic Cancer and Proposal for a New Diagnostic Algorithm: A Multicenter Observational Study. *Diagnostics*, 11(2), 287. https://doi.org/10.3390/diagnostics11020287
21. Ilic, M., & Ilic, I. (2016). Epidemiology of pancreatic cancer. *World Journal of Gastroenterology*, 22(44), 9694. https://doi.org/10.3748/wjg.v22.i44.9694
22. Jemal, A., Siegel, R., Ward, E., Hao, Y., Xu, J., & Thun, M. J. (2009). Cancer Statistics, 2009. *CA a Cancer Journal for Clinicians*, 59(4), 225–249. https://doi.org/10.3322/caac.20006
23. Jung, J. H., Won, S. H., Jung, K., Lee, J. S., Lee, J. C., Kim, J. W., Yoon, Y. S., Hwang, J. H., Han, H. S., & Kim, J. (2024). Analysis of Recent Improvement of Survival Outcomes in Patients with Pancreatic Cancer Who Underwent Upfront Surgery. Gut and liver, 18(4), 737–746. https://doi.org/10.5009/gnl230303

24. Kaur, S., Baine, M. J., Jain, M., Sasson, A. R., & Batra, S. K. (2022). Early diagnosis of pancreatic cancer: challenges and new developments. Biomarkers in Medicine, 6(5), 597–612. https://doi.org/10.2217/bmm.12.69
25. Koopmann, J., Rosenzweig, C. N. W., Zhang, Z., Canto, M. I., Brown, D. A., Hunter, M., Yeo, C., Chan, D. W., Breit, S. N., & Goggins, M. (2016). Serum Markers in Patients with Resectable Pancreatic Adenocarcinoma: Macrophage Inhibitory Cytokine 1 versus CA19-9. *Clinical Cancer Research*, 12(2), 442–446. https://doi.org/10.1158/1078-0432.ccr-05-0564
26. Lim, J. E., Chien, M. W., & Earle, C. C. (2003). Prognostic factors following curative resection for pancreatic adenocarcinoma. Annals of Surgery, 237(1), 74–85. https://doi.org/10.1097/00000658-200301000-00011
27. Lima, T., Barros, A. S., Trindade, F., Ferreira, R., Leite-Moreira, A., Barros-Silva, D., Jerónimo, C., Araújo, L., Henrique, R., Vitorino, R., & Fardilha, M. (2022). Application of Proteogenomics to Urine Analysis towards the Identification of Novel Biomarkers of Prostate Cancer: An Exploratory Study. *Cancers*, 14(8), 2001. https://doi.org/10.3390/cancers14082001
28. Liu, H., Zenati, M. S., Rieser, C. J., Al-Abbas, A., Lee, K. K., Singhi, A. D., Bahary, N., Hogg, M. E., Zeh, H. J., 3rd, & Zureikat, A. H. (2020). CA19-9 Change During Neoadjuvant Therapy May Guide the Need for Additional Adjuvant Therapy Following Resected Pancreatic Cancer. *Annals of surgical oncology*, 27(10), 3950–3960. https://doi.org/10.1245/s10434-020-08468-9
29. Luebeck, E. G. (2020). Genomic evolution of metastasis. *Nature*, 467(7319), 1053–1055. https://doi.org/10.1038/4671053a
30. Martin, L. K., Wei, L., Trolli, E., & Bekaii-Saab, T. (2012). Elevated baseline CA19-9 levels correlate with adverse prognosis in patients with early- or advanced-stage pancreas cancer. *Medical oncology (Northwood, London, England)*, 29(5), 3101–3107. https://doi.org/10.1007/s12032-012-0278-9
31. Murakawa, M., Kawahara, S., Takahashi, D., Kamioka, Y., Yamamoto, N., Kobayashi, S., Ueno, M., Morimoto, M., Sawazaki, S., Tamagawa, H., Ohshima, T., Yukawa, N., Rino, Y., & Morinaga, S. (2023). Risk factors for early recurrence in patients with pancreatic ductal adenocarcinoma who underwent curative resection. *World J Surg Onc.*, 21, 263. https://doi.org/10.1186/s12957-023-03141-3
32. Nassereldine, H., Awada, H., Ali, A. H., Zeineddine, M., Sater, Z. A., & Shaib, Y. (2022). Pancreatic cancer in the MENA region, a bibliometric review. *Ecancermedicalscience*, 16. https://doi.org/10.3332/ecancer.2022.1380
33. Nöthlings, U., Murphy, S. P., Wilkens, L. R., Henderson, B. E., & Kolonel, L. N. (2017). Dietary glycemic load, added sugars, and carbohydrates as risk factors for pancreatic cancer: the Multiethnic Cohort Study. *American Journal of Clinical Nutrition*, 86(5), 1495–1501. https://doi.org/10.1093/ajcn/86.5.1495
34. Okita, Y., Sobue, T., Zha, L., Kitamura, T., Iwasaki, M., Inoue, M., Yamaji, T., Tsugane, S., & Sawada, N. (2022). Association between alcohol consumption and risk of pancreatic Cancer: the Japan Public Health *Center-Based Prospective Study. Cancer Epidemiology Biomarkers & Prevention, 31(11), 2011–2019. https://doi.org/10.1158/1055-9965.epi-22-0216*

35. Parkin, D. M., Boyd, L., & Walker, L. C. (2021). The fraction of cancer attributable to lifestyle and environmental factors in the UK in 2010. British Journal of Cancer, 105(S2), S77–S81. https://doi.org/10.1038/bjc.2011.489
36. Rassi, R. E., Meho, L. I., Nahlawi, A., Salameh, J. S., Bazarbachi, A., & Akl, E. A. (2018). Medical research productivity in the Arab countries: 2007-2016 bibliometric analysis. Journal of Global Health, 8(2). https://doi.org/10.7189/jogh.08.020411
37. Selvasundaram, K., Jayaraman, S., Chinthamani, S. A. M., Nethravathi, K., Ahmad, A. Y. B., & Ravichand, M. (2024). Evaluating the Use of Blockchain in Property Management for Security and Transparency. In Recent Technological Advances in Engineering and Management (pp. 193-197). CRC Press.
38. Ramadan, A., Maali, B., Morshed, A., Baker, A. A. R., Dahbour, S., & Ahmad, A. B. (2024). Optimizing working capital management strategies for enhanced profitability in the UK furniture industry: Evidence and implications. Journal of Infrastructure, Policy and Development, 8(9), 6302.
39. *Fouzdar, A. S., Yamini, S., Biswas, R., Jindal, G., Ahmad, A. Y. B., & Dawar, R. (2024). Considering the Use of Blockchain for Supply Chain Authentication Management in a Secure and Transparent Way. In Recent Technological Advances in Engineering and Management (pp. 259-264).* CRC Press.
40. Feng, Y., Ahmad, S. F., Chen, W., Al-Razgan, M., Awwad, E. M., Ayassrah, A. Y. B. A., & Chi, F. (2024). Design, analysis, and environmental assessment of an innovative municipal solid waste-based multigeneration system integrating LNG cold utilization and seawater desalination. Desalination, 117848.
41. Zhang, L., Ahmad, S. F., Cui, Z., Al Razgan, M., Awwad, E. M., Ayassrah, A. Y. B. A., & Shi, K. (2024). Energy, exergy, hermoeconomic analysis of a novel multi-generation system based on geothermal, kalina, double effect absorption chiller, and LNG regasification. Desalination, 117830.
42. Iqbal, S., Tian, H., Muneer, S., Tripathi, A., & Ahmad, A. Y. B. (2024). Mineral resource rents, fintech technological innovation, digital transformation, and environmental quality in BRI countries: An insight using panel NL-ARDL. Resources Policy, 93, 105074.
43. Geetha, B. T., Gnanaprasuna, E., Ahmad, A. Y. B., Rai, S. K., Rana, P., & Kapila, N. (2024, March). Novel Metrics Introduced to Quantify the Level of Circularity in Business Models Enabled by Open Innovation. In 2024 International Conference on Trends in Quantum Computing and Emerging Business Technologies (pp. 1-6). IEEE.
44. Geetha, B. T., Kafila, K., Ram, S. T., Narkhede, A. P., Ahmad, A. Y. B., & Tiwari, M. (2024, March). Creating Resilient Digital Asset Management Frameworks in Financial Operations Using Blockchain Technology. In 2024 International Conference on Trends in Quantum Computing and Emerging Business Technologies (pp. 1-7). IEEE.
45. Naved, M., Kole, I. B., Bhope, A., Gautam, C. S., Ahmad, A. Y. B., & Lourens, M. (2024, March). Managing Financial Operations in the Blockchain Revolution to Enhance Precision and Safety. In 2024 International Conference on Trends in Quantum Computing and Emerging Business Technologies (pp. 1-6). IEEE.

46. Y. A. B. Ahmad, N. Verma, N. M. Sarhan, E. M. Awwad, A. Arora and V. O. Nyangaresi, "An IoT and Blockchain-Based Secure and Transparent Supply Chain Management Framework in Smart Cities Using Optimal Queue Model," in IEEE Access, vol. 12, pp. 51752-51771, 2024, doi:10.1109/ACCESS.2024.3376605
47. Bani Ahmad, A. Y., Fraihat, B. A. M., Hamdan, M. N., Ayasrah, F. T. M., Alhawamdeh, M. M., & Al-Shakri, K. S. (2024). Examining the mediating role of organizational trust in the relationship between organizational learning and innovation performance: A study of information systems and computer science service firms.
48. Almarshad, M. N., Alwaely, S. A., Alkhawaldeh, B. Y., Al Qaryouti, M. Q. H., & Bani Ahmad, A. Y. (2024). The Mediating Role of Energy Efficiency Measures in Enhancing Organizational Performance: Evidence from the Manufacturing Sector in Jordan.
49. AlKhawaldeh, B. Y. S., Al-Smadi, A. W., Ahmad, A. Y., El-Dalahmeh, S. M., Alsuwais, N., & Almarshad, M. N. (2024). Macroeconomic determinants of renewable energy production in Jordan. International Journal of Energy Economics and Policy, 14(3), 473-481.
50. Ahmad, A. Y., Jain, V., Verma, C., Chauhan, A., Singh, A., Gupta, A., & Pramanik, S. (2024). CSR Objectives and Public Institute Management in the Republic of Slovenia. In Ethical Quandaries in Business Practices: Exploring Morality and Social Responsibility (pp. 183-202). IGI Global
51. Mahafzah, A. H., & Abusaimeh, H. (2018). Optimizing power-based indoor tracking system for wireless sensor networks using ZigBee. International Journal of Advanced Computer Science and Applications, 9(12).
52. Bani Atta, A. A., Ali Mustafa, J., Al-Qudah, S. S., Massad, E., & Ahmad, A. B. (2023). The effect of macroprudential regulation on banks' profitability during financial crises [Specialissue]. Corporate Governance and Organizational Behavior Review, 7(2), 245-258.
53. Cheng, Congbin, Sayed Fayaz Ahmad, Muhammad Irshad, Ghadeer Alsanie, Yasser Khan, Ahmad Y. A. Bani Ahmad (Ayassrah), and Abdu Rahman Aleemi. 2023. "Impact of Green Process Innovation and Productivity on Sustainability: The Moderating Role of Environmental Awareness" Sustainability 15, no. 17: 12945. https://doi.org/10.3390/su151712945
54. Salem, A. A., & Mackenzie, G. G. (2018). Pancreatic cancer: A critical review of dietary risk. *Nutrition Research*, 52, 1–13. https://doi.org/10.1016/j.nutres.2017.12.001
55. Shultz, C. L. (2025). *New Test Detects Early Pancreatic Cancer with 85% Accuracy – and Researchers Say It Costs 'Less Than a Penny*.
56. Sung, H., Ferlay, J., Siegel, R. L., Laversanne, M., Soerjomataram, I., Jemal, A., & Bray, F. (2021). Global Cancer Statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA a Cancer Journal for Clinicians*, 71(3), 209–249. https://doi.org/10.3322/caac.21660
57. Tayyem, R., Hammad, S., Allehdan, S., Al-Jaberi, T., Hushki, A., Rayyan, Y., Al-Natsheh, I., & Bawadi, H. (2022). Dietary patterns associated with the risk of pancreatic cancer: Case-control study findings. *Medicine*, 101(48), e31886. https://doi.org/10.1097/md.0000000000031886
58. Vincent, A., Herman, J., Schulick, R., Hruban, R. H., & Goggins, M. (2021). Pancreatic cancer. *The Lancet*, 378(9791), 607–620. https://doi.org/10.1016/s0140-6736(10)62307-0
59. Yachida, S., Jones, S., Bozic, I., Antal, T., Leary, R., Fu, B., Kamiyama, M., Hruban, R. H., Eshleman, J. R., Nowak, M. A., Velculescu, V. E., Kinzler, K. W., Vogelstein, B., & Iacobuzio-Donahue, C. A. (2020). Distant metastasis occurs late during the genetic evolution of pancreatic cancer. Nature, 467(7319), 1114–1117. https://doi.org/10.1038/nature09515
60. Wu, J., Ahmad, S. F., Ali, Y. A., Al-Razgan, M., Awwad, E. M., & Ayassrah, A. Y. B. A. (2024). Investigating the role of green behavior and perceived benefits in shaping green car buying behavior with environmental awareness as a moderator. Heliyon, 10(9).
61. Yahiya, A., & Ahmad, B. (2024). Automated debt recovery systems: Harnessing AI for enhanced performance. Journal of Infrastructure, Policy and Development, 8(7), 4893.
62. Zheng, J., Guinter, M. A., Merchant, A. T., Wirth, M. D., Zhang, J., Stolzenberg-Solomon, R. Z., & Steck, S. E. (2017). Dietary patterns and risk of pancreatic cancer: a systematic review. Nutrition Reviews, 75(11), 883–908. https://doi.org/10.1093/nutrit/nux038
63. Zhou, X., Xue, F., Li, T., Xue, J., Yue, S., Zhao, S., Lu, H., & He, C. (2024). Exploration of potential biomarkers for early bladder cancer based on urine proteomics. *Frontiers in Oncology*, 14. https://doi.org/10.3389/fonc.2024.1309842