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Association of Cytomegalovirus Seropositivity with IL-1β and Other Cytokines in Breast Carcinoma Patients

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Abstract

Background: Breast cancer is the most frequently diagnosed type of tumor in women worldwide. The Human cytomegalovirus (HCMV) has been detected as an onco-modulatory agent in mammary cells cancer progression, and the Interleukin1β is associated with altered inflammatory signaling and cancer susceptibility.

Methodology: It was a hospital-based case-control study that recorded 120 Iraqi women: 60 with breast cancer, 30 with fibroadenoma, and 30 healthy controls. HCMV IgG levels were quantified using the VIDAS® immunoassay. Serum IL-1β and IL-6 levels were measured by sandwich ELISA.

Results: HCMV IgG seropositivity was significantly elevated in breast cancer patients (81.7%) than in those with fibroadenoma (63.3%) and controls (60.0%) ($p = 0.04$). Serum IL-6 levels were elevated in breast cancer (486.6 ± 228 pg/mL) and those with fibroadenoma (467 ± 225 pg/mL) compared to controls (184.5 ± 58.3 pg/mL; $p < 0.0001$). IL-1β levels were paradoxically lower in breast cancer patients (891 ± 178.4 pg/mL; $p < 0.0001$).

Conclusion: seropositivity of HCMV is independently associated with breast cancer in an Iraqi female, indicating that the close relationship of viral infection and pro-inflammatory genetic predisposition may potentiate carcinogenic risk.

ارتباط إيجابية المصل لفيروس مضخم الخلايا مع إنترلوكين−1 بيتا والسيتوكينات الأخرى لدى مرضى سرطان الثدي

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الخلاصة: يُعد سرطان الثدي أكثر أنواع الأورام شيوعًا بين النساء في جميع أنحاء العالم. وقد تم الكشف عن الفيروس المضخم للخلايا البشري (HCMV) كعامل مُعدِّل للأورام في تطور سرطان خلايا الثدي، كما يرتبط الإنترلوكين 1 والإنترلوكين 6 بيتا بتغيرات في الإشارات الالتهابية وزيادة قابلية الإصابة بالسرطان.
العينات وطرق العمل: كانت هذه دراسة مقارنة بين الحالات والشواهد، أُجريت في أحد المستشفيات، وشملت 120 امرأة عراقية: 60 مصابة بسرطان الثدي، و30 مصابة بالورم الليفي الغدي، و30 امرأة سليمة كمجموعة ضابطة. تم قياس مستويات الأجسام المضادة IgG لفيروس HCMV باستخدام اختبار VIDAS® المناعي. كما تم قياس مستويات الإنترلوكين-1β والإنترلوكين-6 في المصل باستخدام اختبار ELISA الساندويتش.

النتائج: كانت نسبة إيجابية الأجسام المضادة IgG لفيروس HCMV مرتفعة بشكل ملحوظ لدى مريضات سرطان الثدي (81.7%) مقارنةً بمريضات الورم الليفي الغدي (63.3%) والمجموعة الضابطة (60.0%) ($p = 0.04$). كما كانت مستويات الإنترلوكين-6 في المصل مرتفعة لدى مريضات سرطان الثدي (486.6 ± 228 بيكوغرام/مل) ولدى مريضات الورم الليفي الغدي (467 ± 225 بيكوغرام/مل) مقارنةً بالمجموعة الضابطة (184.5 ± 58.3 بيكوغرام/مل؛ $p < 0.0001$). كانت مستويات إنترلوكين-1 بيتا (IL-1β) أقل بشكل غير متوقع لدى مريضات سرطان الثدي (891 ± 178.4 بيكوغرام/مل؛ $p < 0.0001$).

الاستنتاج: يرتبط وجود الأجسام المضادة لفيروس المضخم للخلايا (HCMV) بشكل مستقل بسرطان الثدي لدى امرأة عراقية، مما يشير إلى أن العلاقة الوثيقة بين العدوى الفيروسية والاستعداد الوراثي للالتهاب قد تزيد من خطر الإصابة بالسرطان.

1. Introduction

According to the World Health Organization (WHO), Breast cancer (BC), is the most common recurrent tumor in women worldwide. Globally, an estimated 2.3 million people were diagnosed with breast cancer in 2020 resulting in around 680,000 deaths (Organization, 2025). Cytomegaloviruses (CMV) belong to the β-Herpesviridae subfamily and infect different species including rodents, non-human primates, and humans. The human cytomegalovirus (HCMV), also known as human herpesvirus 5 (HHV5) (Khairallah, Déchanet-Merville and Capone, 2017; Essa, Safar and Raghupathy, 2024). Human cytomegalovirus (HCMV) has a linear, double-stranded DNA genome of 235 ± 1.9 kbp, making it the largest genome among human herpesviruses. It has an E-type genome structure consisting of two large reverse domains called long (L) and short (S) (Ye *et al.*, 2020) Human cytomegalovirus (HCMV) has a very wide spread in the world with an estimated seroprevalence across humans from 45% - 100%, and it has a more serious spread in women than men(Lachmann *et al.*, 2018). Primary infection is typically asymptomatic or manifests as a mild, self-limiting illness in immunocompetent individuals, following primary infection, HCMV establishes lifelong latency within $CD34^+$ hematopoietic progenitor cells in the bone marrow (Lee *et al.*, 2021). Specific strains of HCMV are considered high-risk, most frequently is the HCMV-DB strain, has been demonstrated to induce a pro-oncogenic cellular environment in human mammary epithelial cells (HMECs), characterized by upregulated expression of oncogenes, genes involved in cell proliferation, DNA repair, cell survival, and epithelial to mesenchymal transition (EMT) (El Baba *et al.*, 2022; Jankovic *et al.*, 2025). HCMV exerts its oncogenic influence by interference with numerous critical cellular pathways, including cell cycle regulation, apoptosis, angiogenesis, cellular invasion, and immune evasion(Blanco and Muñoz, 2025). Current evidence suggests a higher prevalence of HCMV proteins and nucleic acids in breast carcinoma tissues compared to non-tumor tissues, further supporting a potential etiological role in breast carcinogenesis(Geisler *et al.*, 2019). The viral infection, including HCMV, triggers an inflammatory response and causes the release of pro-inflammatory cytokines, like interleukin -1 and IL-6, which in turn modulate tumor biology and immune surveillance(Evavold and Kagan, 2022). The IL-1 is a family of cytokines that are have a principal mediators of innate immunity and pro-inflammatory signaling (Boraschi, 2022). IL-1β, encoded by the IL1B gene, is synthesized as an inactive precursor that requires cellular priming, followed by a secondary activating signal, to enable inflammasome-mediated caspase-1 cleavage and subsequent secretion of the mature cytokine (Biology *et al.*, 2020). After release, IL-1β binds to its cognate receptor, IL-1R1. In the context of malignancy, IL-1β exerts pleiotropic effects, encompassing modulation of immune cell activity, angiogenesis promotion, enhancement of cancer cell proliferation, migration, and metastatic dissemination(Bent *et al.*, 2018). Given the interplay between HCMV-induced inflammation, cytokine dysregulation, and genetic predisposition, investigating the combined role of HCMV infection in BC represents a scientifically compelling and clinically relevant avenue of inquiry. This study aimed to investigate the associations between IL-1β, IL-6, and HCMV infection and to evaluate their potential roles as biomarkers in the risk and pathogenesis of BC, compared with fibroadenoma patients and healthy controls.

2. Materials and Methods

2.1. Study Subjects

The Medical Research and Ethics Committee of the Faculty of Medicine, Jabir Ibn Hayyan University for Medical and Pharmaceutical Sciences authorized the study (Approval No.: [1326], dated [3/3/2026]).

2.2. Study Design and Participants

A hospital-based case-control study was conducted between September 1, 2025, and November 10, 2025, in the Babylon Governorate, Iraq. A total of 120 female participants were collected and divided into three groups:

- 60 histologically confirmed BC patients collected from the Babylon Cancer Treatment Center.
- 30 patients with fibroadenoma from the Breast Disease Screening Consultant Clinic at Imam Al-Sadiq Teaching Hospital, serve as a comparative group.
- 30 healthy females recruited from the same institution, serving as the control group. The participants were aged 32–76 years.

2.3. Inclusion Criteria

Participants were eligible for inclusion in the BC group if they have all of the following criteria:

- a confirmed histopathologically diagnosed BC.
- any stage of BC.
- currently receiving chemotherapy.
- aged ≥ 30 years.

2.4. Exclusion Criteria

Participants were excluded from the study are:

- age < 30 years.
- pregnant women.
- presence of benign or malignant conditions other than BC (for the cancer group).
- a history of genetic disorders.

All participants provided written informed consent prior to enrolment. This study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

2.5. Blood Sample Collection and Processing

A total of 3 milliliters was placed into a Gel and clot/activator tube for Serum Separation, which was left to coagulate for 20 minutes at room temperature. Then the blood was centrifuged for 4-5 minutes at 3000 RPM for the detection of the immunological biomarkers.

2.6. Measurement of IL-1β and IL-6 Serum Levels

Serum concentrations of interleukin-1 beta (IL-1β) and interleukin-6 (IL-6) were quantified using commercially available sandwich enzyme-linked immunosorbent assay (ELISA) kits (BT Lab, Shanghai, China), following the manufacturer's instructions. This kit is based on a quantitative immunoassay technique. The microtiter plate has been pre-coated with a target antigen. Standards and samples are added to the wells and incubated. Antibodies in the samples bind to the antigen on the plate. Unbound antibody is washed away during a washing step. A Horseradish Peroxidase (HRP) conjugated detection antibody is then added and incubated. Unbound HRP is washed away during a washing step. TMB substrate is then added and color develops. The reaction is stopped by adding an acidic stop solution and the color changes into yellow which can be measured at 450 nm. The OD of an unknown sample can be converted to concentration, this called Sandwich ELISA.

2.7. Hematological Analysis

Complete blood count (CBC) parameters, including packed cell volume (PCV) and total white blood cell (WBC) count, were performed for all participants using automated hematological analysis.

3. Results

Table1 presents the overview of the main characteristics of the 120 female participants in the three study groups: 60 women with histologically confirmed BC, 30 women with fibroadenoma (a benign breast condition used as a comparison group), and 30 healthy women serve as controls. The table is divided into four sections. Section A shows demographic data; the three groups were comparable according to age (mean ages of 51.1, 47.7, and 50.6 years, respectively; $p = 0.085$), indicating no statistically significant age difference. Section B shows the clinical features of the BC group, including cancer position (the left breast was shown in 50% of cases) and the histological subtype (IDC was the most common (70%) than the other types). A family history of cancer was detected in 35% of BC patients. Section C shows the hematological parameters: BC patients had significantly lower packed cell volume (PCV; the mean was 33.5% vs. 36.5% and 38.6% in the fibroadenoma and control groups, respectively; the $p < 0.0001$), indicating anemia, and significantly higher white blood cell (WBC) counts (mean 9.19×10^9/L vs. 6.66 and 7.63×10^9/L; $p = 0.0016$), which consistent the inflammation associated with cancer-. Section D shows HCMV serological status: BC patients had significantly higher mean of CMV IgG antibody levels (77.15 UA/mL) and a higher seropositivity rate (81.7%) than the fibroadenoma (63.3%) and control (60.0%) groups ($p = 0.04$).

Table1: Demographic, Clinical, Hematological, and HCMV Characteristics of Study Participants

Section	Parameter	Sub-parameter	Breast Cancer (n=60)	Fibroadenoma (n=30)	Control (n=30)	P value
A. Demographic Characteristics	Age (years)	*Mean ± SD*	51.05 ± 10.19	47.67 ± 10.12	50.60 ± 14.53	0.085
		Range	32–76	29–66	33–75	
	Marital Status	*Married*	54 (90.0%)	26 (86.7%)	30 (100%)	—
		Single	3 (5.0%)	4 (13.3%)	0 (0.0%)	
		Widowed	3 (5.0%)	0 (0.0%)	0 (0.0%)	
B. Clinical Characteristics (Breast Cancer Group)	Tumor Site	*Left*	30 (50.0%)	—	—	—
		Right	25 (41.7%)	—	—	
		Both	5 (8.3%)	—	—	
	Histological Type	*IDC*	42 (70.0%)	—	—	—
		ILC	3 (5.0%)	—	—	
		Mixed	2 (3.3%)	—	—	
		Invasive solid papillary ca.	1 (1.7%)	—	—	
	Family History of Cancer	*Yes*	21 (35.0%)	—	—	—
		No	39 (65.0%)	—	—	
C. Hematological Parameters	PCV (%)	*Mean ± SD*	33.47 ± 4.14 [a]	36.53 ± 3.66 [b]	38.61 ± 4.18 [b]	<0.0001
		Range	20–42.9	28.5–42	29.9–47	
	WBC ($\times 10^9$/L)	*Mean ± SD*	9.19 ± 3.29 [a]	6.66 ± 1.59 [b]	7.63 ± 2.40 [b]	0.0016
		Range	2.91–16.4	3.9–11.2	4.8–12.1	
D. HCMV Status	CMV IgG (UA/mL)	*Mean ± SD*	77.15 ± 30.7	36.4 ± 14.2	32.47 ± 11.65	<0.0001
	CMV IgG Seropositivity	*Positive n (%)*	49 (81.7%)	19 (63.3%)	18 (60.0%)	0.04

		Negative n (%)	11 (18.3%)	11 (36.7%)	12 (40.0%)	
IDC: Invasive Ductal Carcinoma; ILC: Invasive Lobular Carcinoma; PCV: Packed Cell Volume; WBC: White Blood Cell count; HCMV: Human Cytomegalovirus; CMV IgG: Cytomegalovirus Immunoglobulin G antibodies. Superscripts (^{a}, ^{b}) denote statistically distinct groups by One-way ANOVA post-hoc analysis. (—) indicates data not applicable to the respective group. * $p < 0.05$ is considered statistically significant.						

Table2 presents the serum concentrations of two inflammatory cytokines, interleukin (IL)-1 β and IL-6, detected in the three study groups. IL-1β levels were inversely related to disease severity: concentrations were higher in healthy controls (1407 ± 580.6 pg/ml), intermediate in the fibroadenoma group (1102 ± 387 pg/ml), and lowest in patients with BC (891 ± 178.4 pg/ml), with a highly significant difference across groups ($p < 0.0001$). In contrast, IL-6 levels were high in both the BC group (486.6 ± 228 pg/ml) and fibroadenoma group (467 ± 225 pg/ml) groups compared to healthy controls (184.5 ± 58.3 pg/ml; $p < 0.0001$).

Table2: Cytokine Levels (IL-1β and IL-6 Serum Concentrations Across Study Groups)

Parameter	Breast Cancer (n=60)	Fibroadenoma (n=30)	Control (n=30)	p-value
IL-1β (pg/ml)	891 ± 178.4^{a}	1102 ± 387^{b}	1407 ± 580.6^{c}	<0.0001
Range	(585-1345)	(644 -1803)	(778.6-2802)	
IL-6 (pg/ml)	486.6 ± 228^{a}	467 ± 225^{a}	184.5 ± 58.3^{b}	<0.0001
Range	(109-957)	(467-930.2)	(100 - 641)	
Superscripts (^{a}, ^{b},^{c}) denote statistically distinct groups by One-way ANOVA post-hoc analysis. * $p < 0.05$ is considered statistically significant.				

4. Discussion

In the present study, the seropositivity level of HCMV IgG was significantly elevated (81.7%; $p = 0.04$) in patients with BC. Blanco and Muñoz (2025) confirmed that HCMV prevalence is consistently higher in breast carcinoma tissues than in adjacent non-tumor or benign breast tissues, and there a specific oncogenic HCMV strains, most notably the HCMV-DB strain, has the capacity to transform human mammary epithelial cells (Blanco and Muñoz, 2025). A 2025 ecological study performed by Jankovic et al. showed a strong and statistically significant inverse correlation between CMV seroprevalence and BC, suggesting a potential onco-protective role for CMV(Jankovic *et al.*, 2025). This paradoxical outcome might be a reflection of the complexity of HCMV–host interactions, where in the immunological effects of chronic CMV infection such as a higher frequency of cytotoxic T lymphocytes and natural killer cells specific to CMV may lead to greater antitumor surveillance in populations with high seroprevalence. Rather than refuting this global ecological trend, the present study's finding of elevated HCMV seropositivity in BC patients is suggested to be reflective of a different underlying pathophysiological scenario where active or reactivated HCMV infection acts on an already-infiltrated or genetically predisposed host and in that setting contributes to promoting rather than protecting a tumoral state. This interpretation is consistent with the dual onco-modulatory model shown by Blanco and Muñoz, in which the effect of HCMV on cancer progression are critically depends on host immune status, viral strain, and tissue-specific factors(Blanco and Muñoz, 2025). The current study found that serum IL-1β concentrations in the BC group were significantly lower than in both the fibroadenoma and control groups. This finding violates the decision of the pro-tumorigenic role of IL-1β in cancer biology, which is generally understood to angiogenesis promotion, cell proliferation of the tumor, migration, and metastatic dissemination. However, this paradox is not without precedent in the literature. Kaplanov et al. demonstrated in a breast cancer that blocking IL-1β reversed tumor associated immunosuppression, suggesting that in established tumors, IL-1β may contribute paradoxically to an immunosuppressive microenvironment that, disrupted, restores antitumor immunity(Kaplanov *et al.*, 2019). A study by Toney et al. (2025) demonstrated enhanced IL-1β-driven invasiveness by tumor-infiltrating B cells specifically in triple-negative BC, Highlighting the importance of local cytokine dynamics rather

than systemic dynamics (Toney *et al.*, 2025). Additionally, the immunosuppressive effects of chemotherapy, to which all BC patients in the present study were exposed, may have contributed to the suppression of systemic IL-1β production, further confounding direct comparisons with the fibroadenoma and control groups. The serum IL-6 levels were significantly elevated in both the BC and fibroadenoma groups compared to healthy controls ($p = 0.0001$), without a statistically significant difference between the two disease groups. This result suggests that IL-6 elevation may represent a broader inflammatory response associated with breast disease rather than being a specific biomarker for malignancy. These findings are similar to a 2025 systematic review and meta-analysis by De La Cruz-Vargas et al., which found that elevated serum IL-6 is significantly associated with a lower overall survival rate among patients. with BC (hazard ratio 3.74; 95% CI: 1.84–7.6), positioning IL-6 As a strong biomarker for predicting diagnosis (De La Cruz-Vargas *et al.*, 2025). The parallel elevation of IL-6 in patients with fibroadenoma observed in the current study may reflect the chronic low-grade inflammatory state associated with benign breast disease, which shares certain immunological features with malignant breast pathology. The role of HCMV in driving IL-6 production within the tumor microenvironment is well-established; Mohamed et al. demonstrated that HCMV-infected tumor-associated macrophages (TAMs) show significantly elevated in the levels of IL-6, IL-8, and MCP-1 compared to their HCMV-negative counterparts, providing a mechanistic link between HCMV infection and the IL-6 elevation observed in the present cohort(Mohamed *et al.*, 2022). The hematological findings of the current study, which found the significantly reduced PCV and elevated WBC counts in BC patients, are consistent with the well-documented hematological consequences of malignancy and its treatment. A 2024 case-control study by Abbas et al. confirmed that BC patients found a significant reduction in hemoglobin, PCV, and red blood cell counts, along with elevated WBC counts, compared to healthy controls, attributing these changes to tumor-induced hematopoietic suppression, chronic inflammation, and the myelosuppressive effects of cytotoxic chemotherapy(Abbas *et al.*, 2024). The elevated WBC count observed in this study may additionally reflect the immune activation driven by HCMV, as HCMV infection is known to induce characteristic lymphocytosis and monocytosis as part of the host immune response to viral replication.

Conclusion

In conclusion, the present study provides evidence that HCMV seropositivity is significantly associated with BC in an Iraqi patient, While the paradoxical reduction in serum IL-1β levels in cancer patients This underscores the complexity of cytokine biology in the context of malignant tumors and their treatment.

Conflicts of Interest

The authors declare no conflict of interests

References

Abbas, A.B. *et al.* (2024) 'Comparison of Hematological Parameters and the Associated Factors Among Women with and without Breast Cancer: A Case-Control Study.', *Breast cancer (Dove Medical Press)*, 16, pp. 877–885. Available at: https://doi.org/10.2147/BCTT.S497313.

El Baba, R. *et al.* (2022) 'Oncogenic and Stemness Signatures of the High-Risk HCMV Strains in Breast Cancer Progression.', *Cancers*, 14(17). Available at: https://doi.org/10.3390/cancers14174271.

Bent, R. *et al.* (2018) 'Interleukin-1 Beta-A Friend or Foe in Malignancies?', *International journal of molecular sciences*, 19(8). Available at: https://doi.org/10.3390/ijms19082155.

Biology, C. *et al.* (2020) 'Interleukin-1 β and Cancer'.

Blanco, R. and Muñoz, J.P. (2025) 'Human Cytomegalovirus Infection and Breast Cancer: A Literature Review of Clinical and Experimental Data', *Biology*, 14(2), p. 174.

Boraschi, D. (2022) 'What Is IL-1 for ? The Functions of Interleukin-1 Across Evolution', 13(April), pp. 1–12. Available at: https://doi.org/10.3389/fimmu.2022.872155.

Essa, S., Safar, H.A. and Raghupathy, R. (2024) 'Cytokine Cytokine responses to major human Cytomegalovirus antigens in mouse model', *Cytokine*, 176(February), p. 156546. Available at: https://doi.org/10.1016/j.cyto.2024.156546.

Evavold, C.L. and Kagan, J.C. (2022) 'Diverse Control Mechanisms of the Interleukin-1 Cytokine Family', 10(June), pp. 1–18. Available at: https://doi.org/10.3389/fcell.2022.910983.

Geisler, J. *et al.* (2019) 'A review of the potential role of human cytomegalovirus (HCMV) infections in breast cancer carcinogenesis and abnormal immunity', *Cancers*, 11(12). Available at: https://doi.org/10.3390/cancers11121842.

Jankovic, M. *et al.* (2025) 'A Potential Oncoprotective Role of Cytomegalovirus Against Breast Cancer: Worldwide Correlation and Survey of Evidence', *Diseases*, 13(6), p. 181.

Kaplanov, I. *et al.* (2019) 'Blocking IL-1β reverses the immunosuppression in mouse breast cancer and synergizes with anti-PD-1 for tumor abrogation.', *Proceedings of the National Academy of Sciences of the United States of America*, 116(4), pp. 1361–1369. Available at: https://doi.org/10.1073/pnas.1812266115.

Khairallah, C., Déchanet-Merville, J. and Capone, M. (2017) 'γδ T cell-mediated immunity to cytomegalovirus infection', *Frontiers in immunology*, 8, p. 105.

De La Cruz-Vargas, J.A. *et al.* (2025) 'Prognostic Relevance of Inflammatory Cytokines Il-6 and TNF-Alpha in Patients with Breast Cancer: A Systematic Review and Meta-Analysis.', *Current oncology (Toronto, Ont.)*, 32(6). Available at: https://doi.org/10.3390/curroncol32060344.

Lachmann, R. *et al.* (2018) 'Cytomegalovirus (CMV) seroprevalence in the adult population of Germany', *PloS one*, 13(7), p. e0200267.

Lee, B.-J. *et al.* (2021) 'Human Cytomegalovirus Host Interactions: EGFR and Host Cell Signaling Is a Point of Convergence Between Viral Infection and Functional Changes in Infected Cells.', *Frontiers in microbiology*, 12, p. 660901. Available at: https://doi.org/10.3389/fmicb.2021.660901.

Mohamed, H.T. *et al.* (2022) 'Inflammatory Breast Cancer: The Secretome of HCMV(+) Tumor-Associated Macrophages Enhances Proliferation, Invasion, Colony Formation, and Expression of Cancer Stem Cell Markers.', *Frontiers in oncology*, 12, p. 899622. Available at: https://doi.org/10.3389/fonc.2022.899622.

Organization, W.H. (2025) *Breast cancer*. Geneva. Available at: https://www.who.int/news-room/fact-sheets/detail/breast-cancer.

Toney, N.J. *et al.* (2025) 'B cells enhance IL-1 beta driven invasiveness in triple negative breast cancer', *Scientific Reports*, 15(1), p. 2211. Available at: https://doi.org/10.1038/s41598-025-86064-1.

Ye, L. *et al.* (2020) 'Functional Profile of Human Cytomegalovirus Genes and Their Associated Diseases: A Review.', *Frontiers in microbiology*, 11, p. 2104. Available at: https://doi.org/10.3389/fmicb.2020.02104.