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HIGHLIGHTS

- Late HIV and AIDS presentation rates remained stable pre- and post-pandemic
- Socio-demographic risk factors for late diagnosis were unchanged after COVID-19
- AIDS presentation strongly predicted higher mortality in both time periods
- No rise in non-AIDS mortality was observed among late presenters post-COVID

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Did the COVID-19 pandemic shift the landscape of late HIV diagnosis?

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Keywords: advanced HIV disease; mortality; COVID-19 pandemic

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ABSTRACT

Background

The COVID-19 pandemic profoundly disrupted healthcare services. This study assessed the impact of the pandemic on the incidence, characteristics, and outcomes of late HIV diagnosis (LD) in Italy.

Methods

All people with HIV (PWH) enrolled in ICONA during 2016–2019 (pre-pandemic) and 2021–2024 (post-pandemic), and diagnosed with HIV within 3 months before enrolment, were included. LD was defined as CD4 <350 cells/mm³ or an AIDS-defining event (ADE) within three months of HIV diagnosis; AIDS presentation (AIDS-P) was considered an ADE at diagnosis. Annual incidence, socio-demographic determinants, and survival outcomes were compared between periods using Poisson regression, Cox proportional hazards models, and Fine-Gray competing risk models.

Results

Among 5,724 newly diagnosed PWH, 56% were enrolled in pre-pandemic and 44% post-pandemic. Overall, 58% presented late and 13% as AIDS-P, with proportions stable across periods. Risk factors for LD — female sex, older age, foreign nationality, heterosexual transmission, lower education, and unemployment — remained consistent, with no significant interaction by time (p = 0.39). During follow-up, 151 deaths occurred. LD and especially AIDS-P were associated with substantially increased all-cause mortality compared with non-LD, particularly within the first-year post-diagnosis. Adjusted hazard ratios were 2.96 for LD and 6.51 for AIDS-P pre-pandemic, and 8.64 and 17.99 post-pandemic. No excess risk was observed for non-AIDS-related mortality.

Conclusions

The prevalence and determinants of LD and AIDS-P in Italy remained stable before and after the COVID-19 pandemic. However, late presentation continues to carry a heavy mortality burden, underscoring the urgent need to strengthen early testing and prompt linkage to care.

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HIGHLIGHTS

- Late HIV and AIDS presentation rates remained stable pre- and post-pandemic
- Socio-demographic risk factors for late diagnosis were unchanged after COVID-19
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INTRODUCTION

The emergence of the COVID-19 pandemic in early 2020 led governments worldwide to implement unprecedented public health measures, aimed at limiting viral transmission and reducing pressure on healthcare systems [1]. Italy, one of the most severely affected countries during the initial stages of the pandemic, was among the first to adopt nationwide restrictions [2]. These interventions significantly disrupted both routine and emergency medical services. A systematic review across multiple countries reported a 37% overall reduction in healthcare system use, with non-Covid related hospital admissions and outpatient visits reduced by 28% and 42%, respectively, particularly among patients with less severe conditions [3].

This profound reshaping of healthcare services has significantly affected the regular management, assistance, and early diagnosis of many chronic non-COVID-19 pathologies, including HIV infection [4]. Surveillance data from Europe and Italy reported a significant decline in new HIV diagnoses in 2020, followed by an upward trend in subsequent years, likely reflecting a rebound effect due to the gradual restoration of routine testing service [5, 6]. Concerningly, recent data showed an increasing number of people with HIV infection (PWH) who presented to care at an advanced stage of infection. In 2023, late HIV diagnoses, defined as CD4 below 350/mm3 or an ADE regardless of CD4 count, at presentation to care, accounted for approximately 54**%** of new HIV cases in Europe and 60**%** in Italy [5, 6].

Beyond the increased rates of late presentation, previous studies have reported a decline in retention in care among PWH following the COVID-19 crisis [7]. Mathematical models further predict a substantial increase in HIV-related morbidity and mortality related to the transitory interruption of HIV prevention and treatment services due to the COVID-19 [8]. Despite these concerns, few studies have directly assessed the impact of pandemic-related restrictions on advanced HIV presentation and associated survival outcomes [9, 10].

This study aims to evaluate the impact of COVID-19 pandemic on the incidence, clinical profile and outcomes of late HIV diagnosis and AIDS presentation by comparing pre-pandemic (2016-2019) and post-pandemic (2021-2024) periods.

MATERIALS AND METHODS

Study design and patients

This is a retrospective analysis of prospectively collected data from the ICONA (Italian Cohort Naïve Antiretrovirals) Foundation cohort, an Italian nationwide observational cohort, set up in 1997, including adult subjects with HIV-1 infection who were ART-naïve at the time of enrolment. Details of the cohort have been described elsewhere [11]. We included all PWH enrolled in ICONA, between 1st January 2016 and 31st December 2024, who received an HIV diagnosis within the three months preceding enrolment in the cohort. Individuals diagnosed in 2020 were excluded given the marked decline in HIV diagnoses during that year, which may have introduced selection bias. Eligible individuals were classified as i) subjects with CD4 count <350 cell/mm3 at HIV diagnosis or ADE regardless of CD4 within 3 months from diagnosis (late diagnosis, LD); ii) subjects presenting to care with ADE regardless of CD4 count (AIDS-presenters, AIDS-P); iii) subjects with CD4 count ≥350 cells/mm3 without a history of ADE (non-late diagnosis, non-LD).

For survival analysis, subjects were stratified in participants without ADE by CD4 cell count (CD≥350 vs. <350 cells/mm3 (LD-CD4<350)) or by ADE presence. The CD4 count considered for the classification was the closest to enrolment in the cohort. Participants without at least one follow-up after enrolment were excluded.

Outcomes and statistical analysis

The main baseline characteristics of the overall population and of participants with LD were described and compared between the two time periods using the chi-square test (Fisher's exact test when appropriate) for categorical variables and the Mann–Whitney or Kruskal–Wallis test, as appropriate, for continuous variables.

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Three main outcomes were evaluated: i) temporal trends in LD and AIDS-P across the two time periods; ii) clinical and socio-demographic characteristics associated with LD in the pre- versus post-pandemic periods; iii) survival outcomes of LD-CD4<350 and AIDS-P according to the time period of diagnosis.

The first outcome was assessed by calculating the annual incidence risk, defined as the proportion of LD divided by the number of ART initiators, in the pre- and post-pandemic periods. For each year, binomial 95% confidence intervals for proportions were calculated using the Clopper–Pearson exact formula. This approach was selected to guarantee nominal coverage [12].

Secondly, factors associated with LD were explored using univariate Poisson regression models. Separate models were fitted for each covariate of interest, acknowledging that confounding is not a reciprocal property. Effect modification was assessed by including interaction terms between time period (pre- vs. post-pandemic) and covariates to determine whether associations differed across time periods. For the third outcome, the association of LD-CD4<350 and AIDS-P with all-cause mortality was assessed through Kaplan–Meier curves, and unadjusted and adjusted Cox proportional hazards models. Survival analysis was performed separately for participants' diagnoses in the pre- and post-pandemic periods, and effect modification by time period was formally tested using the Wald test for interaction. A Fine-Gray competing risk model was performed to evaluate non-AIDS-related mortality, with deaths for other causes treated as competing events. Multivariable models were adjusted for the following baseline covariates– identified a priori as potential confounders on the basis of presumed causal relationships: age, sex at birth, HIV transmission risk group, employment status, alcohol consumption, smoking status, and comorbidities.

All statistical analyses were performed using Stata (18.5, StataCorp LLC, College Station, TX).

RESULTS

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Overall, 5,724 newly diagnosed PWH were enrolled during the study period, with 3,204 (56%) diagnosed in the pre-pandemic and 2,540 (44%) in the post-pandemic period. The main features of the enrolled participants according to the study period are summarized in Table 1.

The population was predominantly male (82.3%), with a median age of 40 years (IQR 31–50), and sexual transmission was the most common route of HIV acquisition (87%). The median nadir CD4 count nadir was 294 cells/mm³ (IQR 106–492). Several differences were observed between the two time periods. The proportion of HIV acquisition among men who have sex with men (MSM) slightly decreased in post-COVID-19 (49% vs 45%; $p < 0.001$), while the proportion of subjects born abroad increased (26% vs 30%; $p < 0.001$). PWH diagnosed after the pandemic were more likely to be employed (50.1 % vs. 54.9%; $p < 0.001$) but less likely to have attained higher education (college/university: 14% vs. 11%; $p < 0.001$). In the LD subgroup, the median CD4 cell count nadir was stable between the two periods (142 vs. 137 cells/mm³; $p = 0.354$). Conversely, the distribution of first-line ART regimens shifted markedly, with increased use of INSTI-based triple therapy (72.5% vs. 83.7%; $p < 0.001$) and dual therapy (2% vs. 4.6%; $p < 0.001$), alongside a substantial decline in PI-based regimens (16.7% vs. 6.6%; $p < 0.001$).

The overall proportions of LD and AIDS-P remained stable across the two study periods with similar fluctuating trend over time. Particularly, in the pre-pandemic period, LD and AIDS-P were observed in 57.4% (95% confidence interval [CI]: 55.7–59.1%) and 12.2% (95% CI: 11.1–13.4%) of cases, respectively. Comparable proportions were seen post-pandemic, with LD in 58.2% (95% CI: 56.3–60.1%) and AIDS-P in 12.9% (95% CI: 11.7–12.6%) of cases [Supplementary Figure 1].

The determinants of LD showed consistent patterns across the pre- and post-COVID-19 periods [Table 2]. Increased risk was associated with female sex, older age, being born abroad, heterosexual transmission, lower educational attainment, and unemployment. A graded association between age and LD risk was observed, with older people experiencing significantly greater risk in both time periods. Heterosexual individuals had a higher risk of LD than MSM, though this difference slightly narrowed post-COVID. The protective effect of higher education was more evident pre-pandemic,

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while employment status and nationality showed similar associations across both periods, albeit somewhat attenuated post-pandemic. No significant interactions with time were observed, indicating that the effect of these factors did not substantially change after the onset of the pandemic (all interaction *p*-values > 0.39) [Table 2].

A total of 151 deaths occurred during the study period. Among participants enrolled pre-pandemic, 118 deaths were recorded over a median follow-up of 66 months (IQR 40, 84), of whom 56 were due to ADEs, 44 to serious non-AIDS events (SNAEs), including six related to COVID-19, and 17 to unknown causes. In contrast, among participants enrolled in the post-pandemic cohort, 33 deaths occurred over a median follow-up of 17 months (IQR: 7, 28): 31 from ADEs, one from a SNAE, and one of unknown cause. In the non-LD population, only two were attributable to AIDS-related mortality, and they both happened in the pre-pandemic period.

The risk of all-cause mortality was significantly higher among LD, particularly AIDS-P, compared with non-LD. This was consistent in both periods and most evident within the first-year post-diagnosis. The 18-month probability of all-cause mortality (95% CI) in the pre-COVID-19 period was 0.46% (95% CI: 0.21, 1.0) for non-LD, 1.4% (95% CI: 0.93, 2.2) for LD-CD4<350, and 8.1% (95% CI: 5.8, 11.4) for AIDS-P (log-rank $p < 0.001$). Corresponding probabilities in the post-pandemic period were 0.3% (95% CI: 0.07, 1.2), 1.5% (95% CI: .0.9, 2.6) and 5.1% (95% CI: 3.1, 8.4) (log-rank $p < 0.001$) [Figure 1, Supplementary Figure 2]. After adjusting for potential confounders, the higher risk of all-cause mortality among LD-CD4<350 and particularly AIDS-P compared to non-LD remained significant in both study periods. In the pre-pandemic period, adjusted hazard ratios (aHRs) were 2.96 (95% CI: 1.75, 5.03; $p < 0.001$) for LD-CD4<350, and 6.51 (95% CI: 3.55–11.95; $p < 0.001$) for AIDS-P, both compared to non-LD. In the post-pandemic period, the corresponding aHRs were even higher: 8.64 (95% CI: 2.03–36.78; $p < 0.001$) for LD-CD4<350, and 17.99 (95% CI: 3.85–84.17; $p < 0.001$) for AIDS-P. The interaction by time period was not statistically significant ($p > 0.10$) [Figure 2].

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Conversely, LD was not associated to an increased risk of non-AIDS-related mortality compared to non-LD in both periods [sub-distribution hazard ratio (SHR) 1.23 (95% CI: 0.66-2.30; *p* 0.51) and following the COVID-19 pandemic onset (SHR 1.17, 95% CI: 0.18-7.20, *p* 0.869) [Figure 3].

DISCUSSION

In this large observational study including newly enrolled PWH in the ICONA cohort before (2016–2019) and after (2021–2024) the onset of the COVID-19 pandemic, the prevalence of late HIV diagnosis and AIDS presentation in Italy remained stable over time, affecting approximately 57–58% and 12–13% of new cases, respectively. The socio-demographic profile of those at risk also remained essentially unchanged, with no evidence of shifts in the strength or direction of key associations across the two periods.

These findings are in line with national surveillance data, which reported similar proportion of late diagnosis (58% of new HIV diagnoses in 2019 and 60% in 2023) and AIDS presentation (23.8% in 2019 and 25.5% in 2023) in pre- and post-pandemic periods [5]. When considering new HIV diagnoses in the context of national HIV testing data in Italy, national data from 2018 to 2023 indicate largely stable temporal trends, with almost a million tests performed, not including hospitalized patients and blood/organ donors. However, as expected, a marked decrease was observed in 2020. Overall, the reported temporal trends in HIV testing rates and HIV diagnoses were similar during this period [13]. Additionally, in line with our results, Italian surveillance data do not indicate a marked shift in the socio-demographic characteristics of individuals with LD between the pre- and post-pandemic periods. Although gradual changes have been observed—such as a higher proportion of AIDS presentations among older individuals, people born abroad (33.1%), and MSM (31%), and a decline among women—these appear to be indicative of ongoing epidemiological trends rather than a clear transition due to the COVID-19 pandemic. This data is consistent with findings from other settings, including a study from Poland showing no pandemic-related changes in the prevalence or characteristics of late HIV diagnosis [14] .

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Previous reports on the impact of COVID-19 pandemic on HIV epidemiology have yielded conflicting findings. Indeed, while evidence consistently indicates a marked reduction in HIV-testing during the early phase of pandemic, as a result of lockdown and restriction measures, across different settings [15], data on the impact of pandemic on HIV diagnosis and, particularly on late HIV diagnosis, appear more heterogeneous. Several reports from different healthcare settings documented a decrease in HIV diagnosis during the early phase of the pandemic [4, 9, 16–18], while others found no substantial change, especially among high-risk subpopulations [19] or even an increase of HIV diagnosis [20]. Notably, a Dutch study reported that undiagnosed individuals with HIV indicator conditions, especially those with subtler clinical manifestations, were less likely to access care during lockdown [4]. Consistently, a large retrospective cohort study including data from 44 countries, reported an increased proportion of positive tests in the very early phase of the pandemic, likely reflecting a more selective testing strategy focused on symptomatic individuals or those perceived to be at higher risk [20] . Taken together, these findings, alongside reduced routine testing, may partially explain the delays in HIV diagnosis observed during and after the pandemic [2], as well as the increase in late HIV diagnoses over the same period reported in several studies [4, 10, 16, 21], although this data has not been consistently confirmed.

In our cohort, we did not observe an apparent increase in late diagnoses during the post-pandemic period; notably, median CD4 counts among individuals with LD were similar across both timeframes. However, this finding should be interpreted with caution, as the data originate from ICONA centres, which include most of the referral national HIV centres and may not fully reflect national-level trends. In addition, most of the available studies focused on the early phase of the pandemic (2020–2021), when the most stringent restriction measures were in place, whereas our analysis spans a longer period (2021–2024), potentially diluting short-term effects on late diagnosis. Of note, the absolute number of new HIV diagnoses declined during the pandemic and early post-pandemic period in the ICONA cohort, mirroring the surveillance in Italy.

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Although the long-term impact of the pandemic-related health-care disruption on survival remains uncertain, modelling studies from Sub-Saharian Africa predicted that interruptions of HIV testing and ART distribution due to COVID-19 could significantly increase mortality within one year [22]. Real-world data further suggest a significant increase in AIDS deaths due to late HIV diagnosis (6.9% in 2020 vs 13.9% in 2021), despite an overall decrease in HIV/AIDS diagnoses and HIV-related death, highlighting the negative impact of COVID-19 control measures on HIV programs [16] .

Notably, our study is among the few that have focused on the long-term outcomes of the COVID-19 outbreak and the subsequent disruption of healthcare programs, particularly in late HIV diagnosis, as it relates to survival [16, 23]. In line with previous evidence [24], late presentation to care and, in particular, AIDS presentation, were strongly associated with an increased all-cause mortality risk in both observation periods in our study, with some evidence suggesting this risk may have been more pronounced in the post-pandemic period. In fact, although the interaction by time period was not statistically significant, the relatively higher hazard ratios observed post-pandemic suggest a possible trend toward worse outcomes in the more recent years.

Although previous evidence documented excess mortality among PWH during the initial phase of the COVID-19 pandemic, largely driven by COVID-19–related deaths [25], we did not observe significant differences in non-AIDS-related mortality between the two periods. This finding suggests that, in our study, the mortality burden among late presenters was primarily driven by AIDS-related causes rather than by comorbid conditions. These observations, although consistent with previous reports [16], should be interpreted with cautiona. Longer-term follow-up will be essential to confirm these trends and to determine the full impact of pandemic-related disruptions on HIV care outcomes.

This study has several limitations. First, its observational design makes it susceptible to residual confounding from unmeasured variables, such as behavioural or social factors not fully captured in the dataset. Secondly, the relatively limited follow-up period in the post-pandemic phase may have constrained our ability to fully assess long-term survival trends or the delayed effects of late HIV diagnosis. Additionally, the study may be underpowered to detect interaction effects, particularly

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regarding time as a potential effect modifier for mortality. Future studies with larger sample sizes and extended follow-up are needed to explore these associations more robustly. Furthermore, our analysis of the pandemic's impact on survival in LD and AIDS-p was restricted to all-cause and non-AIDS-related mortality, due to the relatively small sample and the lack of AIDS-related death in non-LD population in the post-pandemic period, limiting further conclusions on mortality associations. Finally, incomplete or misclassified data on causes of death—particularly in distinguishing HIV-related from COVID-19-related mortality—may limit the interpretation of specific mortality trends.

CONCLUSIONS

In conclusion, our findings indicate that the frequency and socio-demographic pattern of late HIV diagnoses remained stable before and after the COVID-19 pandemic. Late presentation and especially AIDS presentation were consistently associated with increased mortality, with some indication that this risk may have been more pronounced in the post-pandemic period. Although no significant differences emerged in non-AIDS-related events, the potential long-term impact of pandemic-related disruptions warrants continued monitoring. These results highlight the urgent need to enhance early HIV testing [26] and linkage to care.

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***Ethics* approval**

The ICONA Foundation study was approved by the local ethics committees of participating clinical sites. All patients signed a consent form for study participation and processing of data in accordance with the ethical standards of the Committee on Human Experimentation and the Helsinki Declaration (last amended in October 2013).

Competing interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

GMi: none**. AM**: Received speaker honoraria from Gilead Sciences and ViiV Healthcare; travel fees; and participated in advisory boards sponsored by ViiV Healthcare, independent of the submitted work. **AR**: none. **LT**: Attended advisory boards, served as consultant, or received grants for conference participation from Gilead Sciences and ViiV Healthcare; research grants for her institution from Gilead Sciences, independent of the submitted work. **IL:** none. **VM**: Received

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Author's contributions

Conception: GMi, AM and AA. Study design: AM, AR, ACL, and AA. Accessing, verifying of data and statistical analysis: AR and ACL. Draft of the manuscript: GMi and AM. Review of the article and critical revision for important intellectual content: all the authors. Reading and final approval of the submitted version: all the authors. Supervision: ACL and AA.

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Data Availability Statement

The data sets generated during the current study are not publicly available because they contain sensitive data to be treated under data protection laws and regulations. Appropriate agreement of data sharing can be arranged after a reasonable request to the corresponding author.

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References

[1] WHO. *Global excess deaths associated with COVID-19 (modelled estimates)*, https://www.who.int/data/sets/global-excess-deaths-associated-with-covid-19-modelled-estimates (19 May 2023).

[2] CONSIGLIO DEI MINISTRI. DECRETO DEL PRESIDENTE DEL CONSIGLIO DEI MINISTRI 9 marzo 2020 Ulteriori disposizioni attuative del decreto-legge 23 febbraio 2020, n. 6, recante misure urgenti in materia di contenimento e gestione dell'emergenza epidemiologica da COVID-19, applicabili sull'intero territorio nazionale. (20A01558).

[3] Moynihan R, Sanders S, Michaleff ZA, et al. Impact of COVID-19 pandemic on utilisation of healthcare services: a systematic review. *BMJ Open* 2021; 11: e045343.

[4] Hensley KS, Jordans CCE, van Kampen JJA, et al. Significant Impact of Coronavirus Disease 2019 (COVID-19) on Human Immunodeficiency Virus (HIV) Care in Hospitals Affecting the First Pillar of the HIV Care Continuum. *Clin Infect Dis* 2022; 74: 521–524.

[5] Regine V., Pugliese L., Ferri M., et al. Notiziario dell'ISS (volume 37 - numero 11 novembre 2024) - Aggiornamento delle nuove diagnosi di infezione da HIV e dei casi di AIDS in Italia al 31 dicembre 2023, https://www.epicentro.iss.it/aids/pdf/coa-2024.pdf (2024, accessed 20 August 2025).

[6] European Centre for Disease Prevention and Control, World Health Organization. *HIV/AIDS surveillance in Europe 2022 : 2021 data*. SE: European Centre for Disease Prevention and Control, https://data.europa.eu/doi/10.2900/818446 (2022, accessed 6 June 2025).

[7] Guaraldi G, Borghi V, Milic J, et al. The Impact of COVID-19 on UNAIDS 90–90–90 Targets: Calls for New HIV Care Models. *Open Forum Infectious Diseases* 2021; 8: ofab283.

[8] Lesosky M, Myer L. Modelling the impact of COVID-19 on HIV. *The Lancet HIV* 2020; 7: e596–e598.

[9] Mazzitelli M, Ciccullo A, Baldin G, et al. Has COVID-19 changed the approach to HIV diagnosis?: A multicentric Italian experience. *Medicine* 2021; 100: e27418.

[10] Van Bremen K, Monin M, Schlabe S, et al. Impact of COVID-19 on HIV late diagnosis in a specialized German centre. *HIV Medicine* 2022; 23: 1209–1213.

[11] Monforte A d'Arminio, Lepri AC, Rezza G, et al. Insights into the reasons for discontinuation of the first highly active antiretroviral therapy (HAART) regimen in a cohort of antiretroviral naïve patients: *AIDS* 2000; 14: 499–507.

[12] Clopper CJ, Pearson ES. THE USE OF CONFIDENCE OR FIDUCIAL LIMITS ILLUSTRATED IN THE CASE OF THE BINOMIAL. *Biometrika* 1934; 26: 404–413.

[13] Lucia Pugliese, Vincenza Regine, Anna Caraglia, et al. IL NUMERO DI TEST HIV EFFETTUATI IN ITALIA DAL 2018 AL 2023: PRIMI RISULTATI DEL PROGETTO "PRONTI". *Not Ist Super Sanità*; 38: 7–12.

Journal Pre-proof

[14] Wójcik-Cichy K, Piekarska A, Jabłonowska E. Has COVID-19 Changed the Incidence and Profile of Late Presenters for HIV Infection in Lodz, Polish Reference Centre, Poland? *JCM* 2024; 13: 4121.

[15] Ojukwu E, Pashaei A, Maia JC, et al. Evaluating the impact of COVID-19 on the HIV care continuum across global income levels: a mixed-methods systematic review. *AIDS Res Ther* 2025; 22: 115.

[16] Andrade LA, De França Amorim T, Da Paz WS, et al. Reduced HIV/AIDS diagnosis rates and increased AIDS mortality due to late diagnosis in Brazil during the COVID-19 pandemic. *Sci Rep*; 13. Epub ahead of print 27 December 2023. DOI: 10.1038/s41598-023-50359-y.

[17] Wang J-S, Kim EJ, Kim G, et al. Trends in HIV testing and Seroprevalence among key populations at public health centers in South Korea, 2011–2023: a nationwide analysis. *BMC Public Health* 2025; 25: 4338.

[18] Kuehn BM. Reduced HIV Testing and Diagnoses During COVID-19 Pandemic. *JAMA* 2022; 328: 519.

[19] Jalil CM, Teixeira SLM, Coutinho C, et al. Impact of COVID-19 Pandemic on HIV Testing, Recent Infections, and Annualized Incidence Among Cisgender Men Who Have Sex With Men and Transgender Women in Brazil. *JAIDS Journal of Acquired Immune Deficiency Syndromes* 2025; 98: 12–19.

[20] Rick F, Odoke W, Van Den Hombergh J, et al. Impact of coronavirus disease (COVID-19) on HIV testing and care provision across four continents. *HIV Medicine* 2022; 23: 169–177.

[21] Elizalde-Barrera CI, Juarez-Mendoza CV. Late Diagnosis at Entry on Care in an HIV Clinic in Mexico City: Possibly COVID-19 Pandemic Impact. *Curr HIV Res* 2023; 21: 248–253.

[22] Jewell BL, Mudimu E, Stover J, et al. Potential effects of disruption to HIV programmes in sub-Saharan Africa caused by COVID-19: results from multiple mathematical models. *The Lancet HIV* 2020; 7: e629–e640.

[23] Stijnberg D, McKee M, Commiesie E, et al. Evaluating the Effects of the COVID-19 Pandemic on HIV Testing, Enrollment, ART Use and Mortality in Suriname Using Interrupted Time Series Analysis. *AIDS Behav* 2025; 29: 2189–2195.

[24] Mondi A, Cozzi-Lepri A, Tavelli A, et al. Persistent poor clinical outcomes of people living with HIV presenting with AIDS and late HIV diagnosis – results from the ICONA cohort in Italy, 2009-2022. *International Journal of Infectious Diseases* 2024; 142: 106995.

[25] Dhungel S, Ward MK, Barreto GA, et al. Excess Mortality Among People with HIV in Florida During the Initial Onset of the COVID-19 Pandemic: A Surveillance-Based Analysis. *AIDS Behav*. Epub ahead of print 30 December 2025. DOI: 10.1007/s10461-025-05014-0.

[26] Gatechompol S, Avihingsanon A, Putcharoen O, et al. COVID-19 and HIV infection co-pandemics and their impact: a review of the literature. *AIDS Res Ther* 2021; 18: 28.

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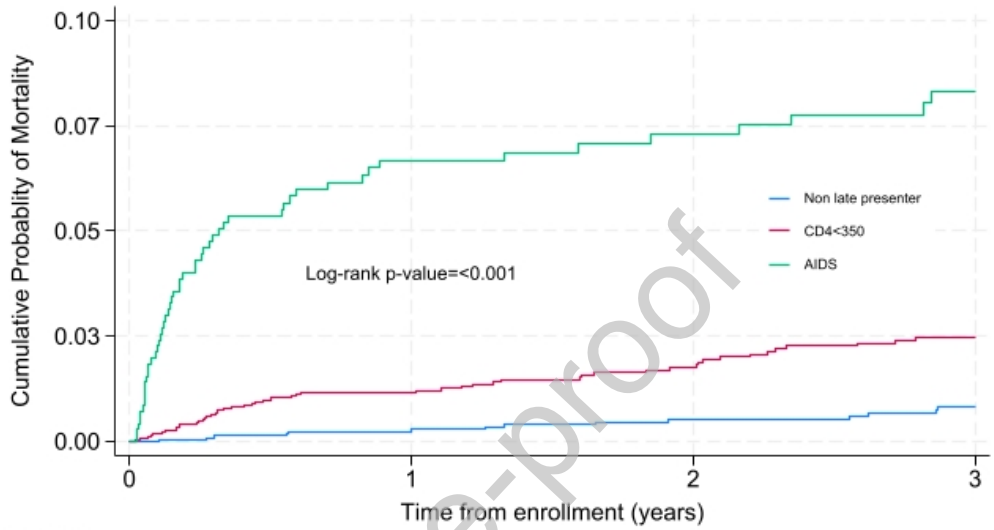
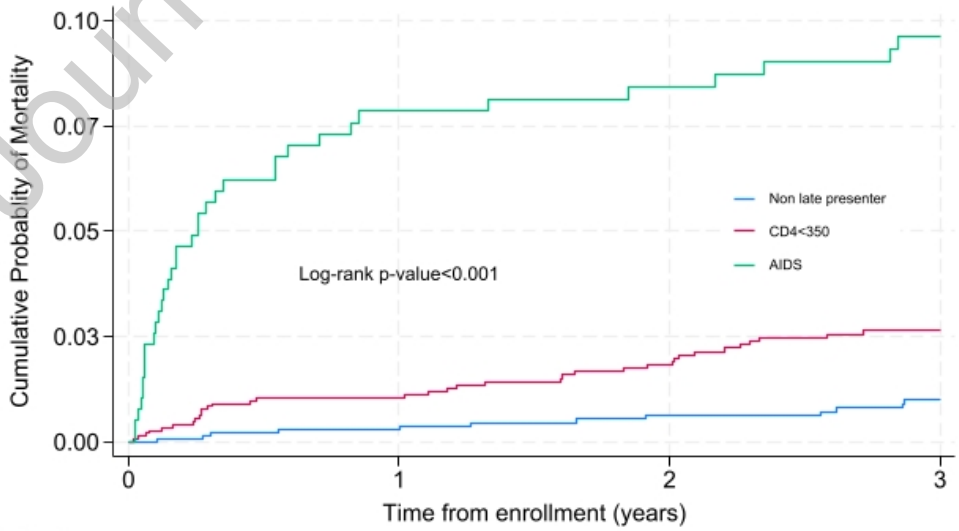
Figure 1. Estimated probability of all-cause mortality by time period (A. overall; B. pre-pandemic; C. post pandemic) and stratified by CD4 cell count [non-LD vs LD-CD4<350] and AIDS-defining event.

A. All-cause mortality overall, with stratification



Number at risk				
non LP	2416	1906	1498	1187
CD4<350	2590	2029	1590	1275
AIDS	718	527	410	333

B. **All-cause mortality, pre-pandemic with stratification**



Number at risk				
non late presenter	1364	1244	1143	1054
CD4<350	1449	1316	1226	1134
AIDS	391	334	310	290

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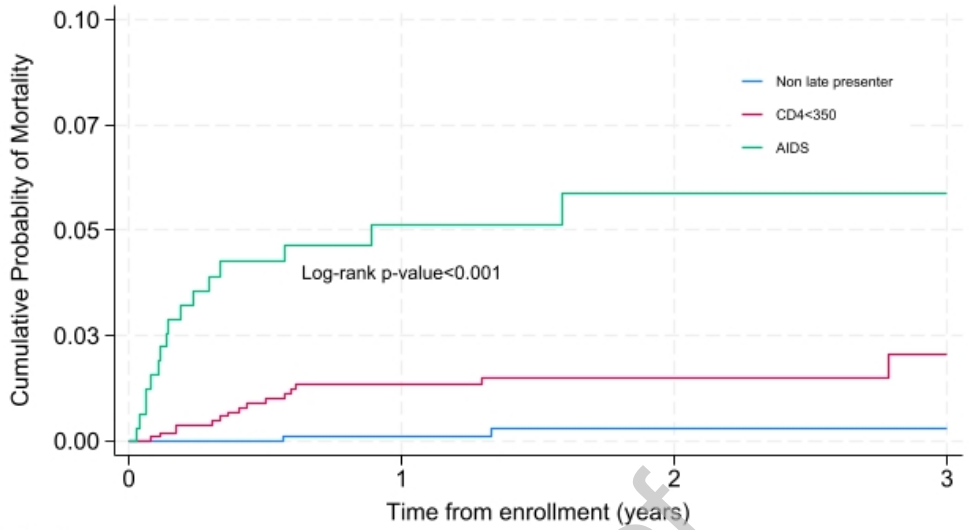
C. **All-cause mortality, post-pandemic with stratification**



Number at risk				
non late presenter	1052	662	355	133
CD4<350	1141	713	364	141
AIDS	327	193	100	43

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Figure 2. Hazard ratio of all-cause mortality stratified by late diagnosis and time period

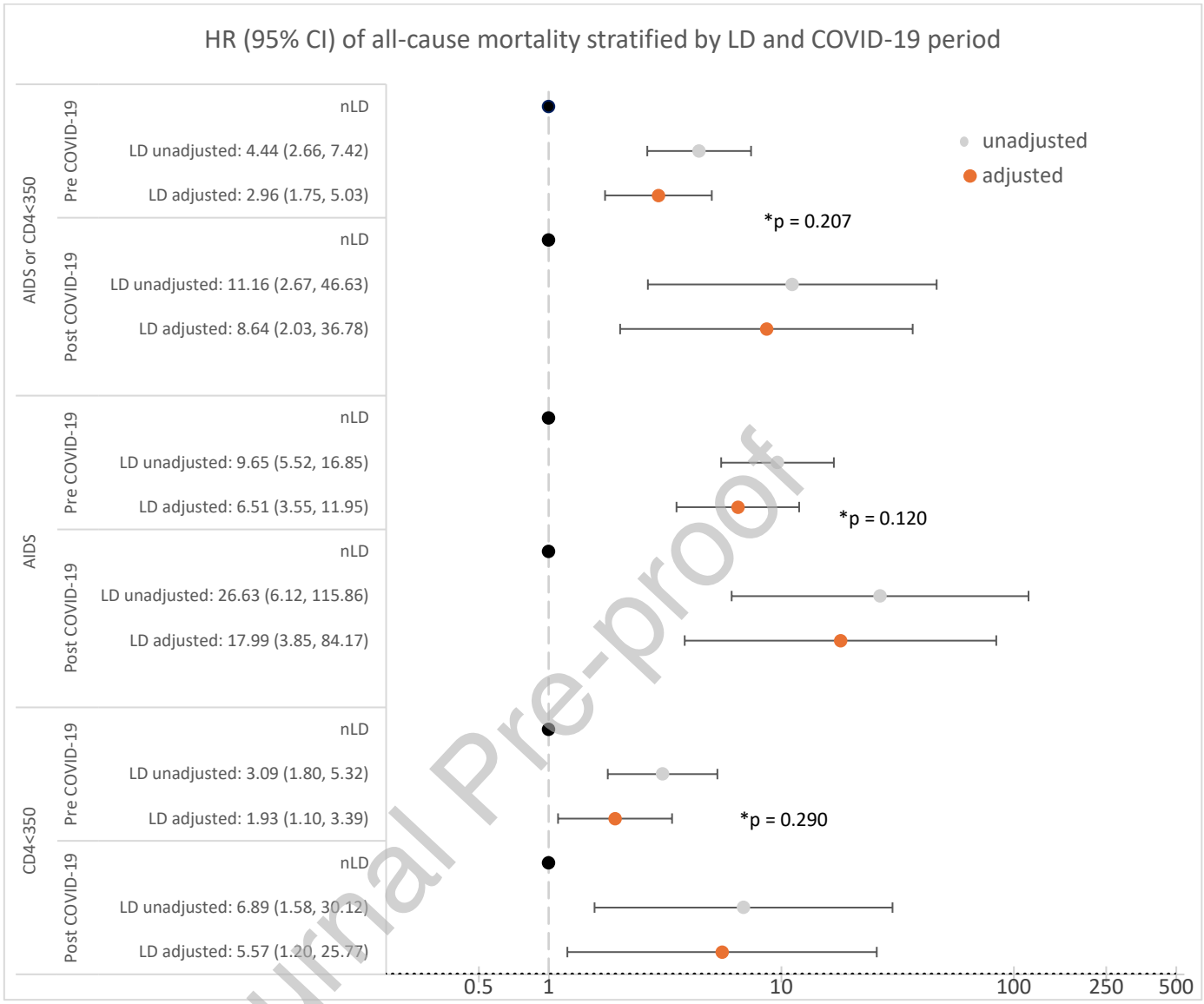

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Figure 3. Sub-distribution hazard ratio of non-AIDS related mortality by late diagnosis and time period

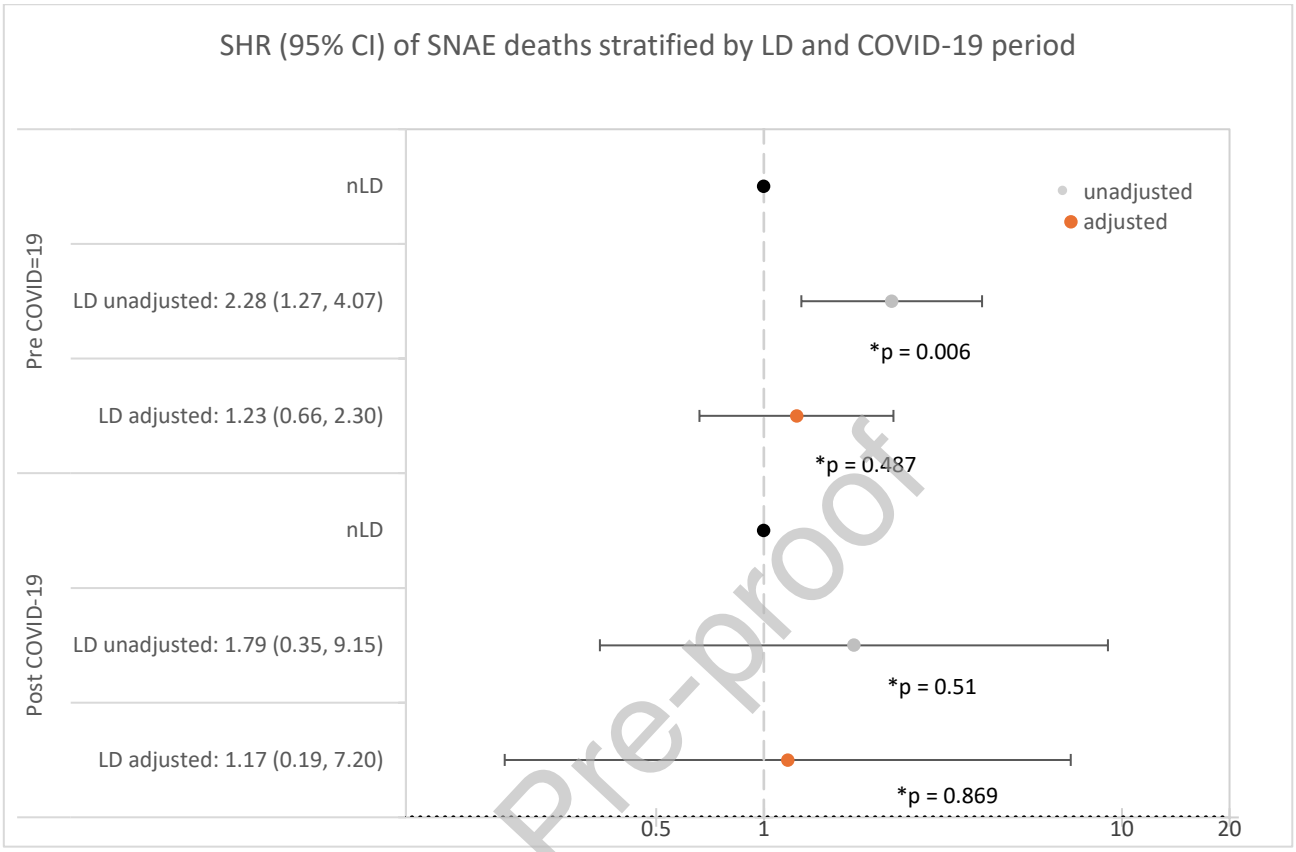

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Table 1. Participants baseline characteristics according to time period of HIV diagnosis

	Pre-COVID [n=3,204; 56%]	**Post-COVID [n=2,520; 44%]**	**Total [n=5,724]**	**p-value**
Overall population				
Female gender, n (%)	579 (18%)	434 (17%)	1,013 (17.7%)	0.40
Age, years, median (IQR)	40 (31-49)	41 (32-51)	40 (31-50)	<0.001
Mode of HIV transmission, n (%)				<0.001
- MSM	1,578 (49%)	1,135 (45%)	2713 (47%)	
- Heterosexual	1,274 (40%)	1,029 (41%)	2,303 (40%)	
- PWID	132 (4%)	107 (4%)	239 (4%)	
Italian nationality, n (%)	2,380 (74%)	1,763 (70%)	4,242 (72%)	<0.001

CD4 cell count nadir, cell/mm3 (IQR)	297 (107-497)	291 (104-491)	294 (106-492)	0.17
Late HIV diagnosis, n (%)	1,840 (57%)	1,568 (58%)	3,308 (58%)	0.50
AIDS presentation n (%)	391 (12%)	327 (13%)	718 (13%)	0.38
First-line ART				
- Dual regimen	103 (3%)	242 (10%)	345 (6%)	<0.001
- INSTI-based	2,196 (69%)	1,997 (79%)	4,193 (73%)	
- PI/booster-based	434 (14%)	122 (5%)	556 (10%)	
- NNRTI-based	289 (9%)	123 (5%)	412 (7%)	
Comorbidities				
- Cardiovascular	33 (1%)	18 (1%)	51 (1%)	0.21
- Diabetes	77 (2%)	40 (2%)	117 (2%)	0.03
- HBV and/or HCV co-infection	136 (4%)	85 (3%)	221 (4%)	<0.001
Education level, n (%)				
- Primary/secondary school	1,384 (43%)	807 (32%)	2,191 (38%)	<0.001
- College/university	434 (14%)	280 (11%)	714 (13%)	
Employment status, n (%)				<0.001
- Unemployed	394 (12%)	263 (10%)	657 (12%)	
- Employed/self-employed	1,604 (50%)	1383 (59%)	2987 (52%)	
- Student/occasional	182 (6%)	100 (4%)	282 (5%)	
- Retired/housewife	134 (4%)	128 (5%)	262 (5%)	
LD population				
CD4 cell count nadir, cell/mm3 (IQR)	142 (46, 249)	137 (41, 244)	140 (44, 247)	0.35
CD4 cell count at diagnosis, cell/mm3 (IQR)	144 (47, 253)	138 (42, 245)	141 (45, 249)	0.30
log10 HIV-RNA at ART	5.22 (5, 6)	5.45 (5, 6)	5.31 (5, 6)	<0.001
Total Drugs				
0	4 (0.2%)	5 (0.3%)	9 (0.3%)	<0.001

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	1 2 (0.1%)	1 (0.1%)	3 (0.1%)	
	2 36 (2%)	67 (4.6%)	103 (3.1%)	
	3 1733 (94.2%)	1387 (94.5%)	3120 (94.3%)	
	4 65 (3.5%)	8 (0.5%)	73 (2.2%)	
First-line ART				
- Dual regimen	36 (2%)	67 (4.6%)	103 (3.1%)	<0.001
- INSTI-based	1334 (72.5%)	1229 (83.7%)	2563 (77.5%)	
- NNRTI-based	82 (4.5%)	59 (4%)	141 (4.3%)	
- Other	80 (4.3%)	16 (1.1%)	96 (2.9%)	
- PI/booster-based	308 (16.7%)	97 (6.6%)	405 (12.2%)	

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Table 2. Prevalence risk ratio of LD by socio-demographic characteristics

	RISK RATIO OF LD (95%CI)		INTERACTION P-VALUE*
	PRE-COVID	**POST-COVID**	
Sex at birth			0.759
Male	1	1	
Female	1.13 (1.01-1.27)	1.10 (0.97-1.26)	
Age			0.957
<30 years old	1	1	
30-39 years old	1.35 (1.16-0.57)	1.25 (1.04-1.50)	
40-49 years old	1.59 (1.37-1.84)	1.51 (1.27-1.81)	
50-59 years old	1.74 (1.49-2.03)	1.76 (1.47-2.11)	
60-69 years old	1.85 (1.51-2.28)	1.78 (1.42-2.23)	
≥70 years old	2.32 (1.70-3.18)	2.10 (1.52-2.90)	
Nationality			0.391
Non-Italian	1	1	
Italian	0.86 (0.78-0.96)	0.92 (0.83-1.03)	
Transmission route			0.610
MSM	1	1	
Heterosexual	1.43 (1.30-1.58)	1.38 (1.24-1.55)	
PWID	1.12 (0.87-1.43)	1.26 (0.97-1.62)	
Education			0.601
Primary school	1	1	
Secondary school	0.76 (0.61-0.95)	0.86 (0.59-1.25)	
College University	0.59 (0.45-0.75)	0.75 (0.50-1.12)	
Employment			0.982
Unemployed	1	1	
Employed/self-employed	0.95 (0.82-1.09)	0.90 (0.76-1.06)	
Student/occasional	0.71 (0.55-0.91)	0.70 (0.50-0.97)	
Retired/Housewife	1.30 (1.04-1.64)	1.19 (0.93-1.53)	

**interaction test socio-demographic characteristics and time-period*

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Declaration of Interest Statement

☐ 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.

☐ The author is an Editorial Board Member/Editor-in-Chief/Associate Editor/Guest Editor for this journal and was not involved in the editorial review or the decision to publish this article.

☒ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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