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Age and full blood count parameters predict survival in acute myeloid leukaemia at a Cape Town tertiary academic centre

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Background: Acute myeloid leukaemia (AML) is a common and aggressive haematological neoplasm. Limited studies of AML in South Africa have shown differences in age at diagnosis and overall survival (OS) compared to international studies.

Aim: To determine the demographics, subtype and OS of AML.

Setting: The study was conducted at the National Health Laboratory Service at Tygerberg Hospital, Cape Town, South Africa.

Methods: Patients with newly diagnosed AML from 2015 to 2018 were identified. The diagnostic subtype and prognostic group for each AML was determined. Survival analysis was performed.

Results: Ninety patients were included. The median age of adults was 54 years (interquartile range [IQR] 38 years – 65 years, $n = 77$), and for children was 2 years (IQR 2 years – 7 years, $n = 13$). The male-to-female ratio was 1:1.4. Acute promyelocytic leukaemia (21%) and AML myelodysplasia related (19%) were the commonest subtypes. The 3-year OS in children, adults <60 years and adults ≥60 years was 46%, 21% and 3%, respectively. Adverse risk group increased risk of death ($p = 0.003$, $n = 38$). Age, white cell count and platelet count were independent risk factors for death.

Conclusion: In contrast to high-income countries, our findings show a younger age at AML diagnosis, a female predominance and a lower OS. Age and full blood count (FBC) parameters are important predictors for OS.

Contribution: The findings complement other studies published in South Africa, showing younger age at diagnosis and inferior OS of AML, while highlighting the importance of FBC findings.

Keywords: acute myeloid leukaemia; South Africa; Africa; survival; Cape Town; leukemia.

Introduction

Acute myeloid leukaemia (AML) is a malignancy characterised by the proliferation of abnormally differentiated haematopoietic cells in the bone marrow and blood.[1] Acute myeloid leukaemia can arise *de novo* or secondary to antecedent haematological disorders, such as myelodysplastic syndrome (MDS) and myeloproliferative neoplasm (MPN), secondary to germline predisposition conditions or secondary to prior chemotherapy or radiation therapy.[2]

The annual incidence of AML in high-income countries is 2.5–5.4 per 100 000 persons.[3,4,5,6,7,8] Acute myeloid leukaemia in adults is most frequently diagnosed in the 6th decade of life, and there is a male predominance.[4,5,6,7,8,9] Data from South Africa suggest differing epidemiological trends, with a younger median age at diagnosis compared to high-income countries.[10,11,12] Acute myeloid leukaemia diagnoses peak in winter, suggesting that seasonal triggers may be involved in the aetiology.[13,14] Seasonal patterns of AML diagnosis in South Africa have not been studied. The 5-year relative survival of AML in the United States (US) is 32.9%.[4] Studies in South Africa have shown inferior overall survival (OS) for patients with

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AML, with an 18% crude 1-year OS for adults with AML and a 29.5% 5-year OS for children with AML.[10,15]

Acute myeloid leukaemia is sub-classified according to the World Health Organization (WHO) based on defining genetic abnormalities, associated conditions or differentiation.[2] Differences in the prevalence of the defining genetic abnormalities have been noted between South African and global patient populations. Acute promyelocytic leukaemia (APL) and AML with *RUNX1::RUNX1T1* fusion are more common in the South African setting, while AML with nucleophosmin protein-1 gene (*NPM1*) mutation is less common.[9,10,11,16,17,18,19,20] Genetic factors play a crucial role in determining prognosis.[16] A normal karyotype is present in 45% of AML cases, although lower frequencies have been reported in South Africa.[12,21] In such cytogenetically normal-acute myeloid leukaemia (CN-AML), mutations in genes such as *NPM1*, FMS-like tyrosine kinase 3 (*FLT3*) and CCAAT enhancer-binding protein alpha (*CEBPA*) provide valuable insights into prognosis.[16,22]

The 2022 European LeukaemiaNet (ELN) guideline is used to stratify adult patients with AML into favourable, intermediate and adverse prognostic groups based on cytogenetic and molecular factors.[16] In children, AML is stratified according to the 2012 International Berlin-Frankfurt-Munster (BFM) Study Group, which is similar to the ELN stratification but specifies additional mutations seen more commonly in paediatric AML.[23] Acute promyelocytic leukaemia (APL), a subtype of AML, is characterised by the promyelocytic leukaemia (PML) and retinoic acid receptor alpha (RARA) fusion (*PML::RARA*) and is associated with a favourable prognosis. Acute promyelocytic leukaemia and hyperleukocytosis are considered medical emergencies because of early haemorrhagic risk and leukostasis, respectively.[24,25] Acute promyelocytic leukaemia is not included in the ELN AML risk stratification but rather has its own Sanz risk scoring system to predict risk of early death,[26,27] although it is considered within the favourable risk group according to the BFM risk classification.[23]

In AML, it has been reported that genetic characteristics account for two-thirds of the variation in outcomes, with the remainder attributed to demographic and treatment-related factors.[19] This study aimed to document the demographics, subtype and survival of patients with AML at a tertiary hospital in Cape Town, South Africa.

Methods

Study setting

This laboratory-based study was conducted at the National Health Laboratory Service (NHLS) haematology department, Tygerberg Hospital (TBH), Cape Town, South Africa. Tygerberg Hospital is a tertiary public sector hospital. During the study period, patients with AML 13 years and younger were managed by the Paediatric Oncology unit, and those ≥14 years old were managed by the Clinical Haematology unit.

During the study period, adult patients with AML who were fit for intensive chemotherapy, based on age, performance status and co-morbidities, were managed with '7+3' chemotherapy induction using daunorubicin and cytarabine, and were consolidated with two to three cycles of high-dose cytarabine. Patients who were unfit for intensive chemotherapy received either low-dose cytarabine or hydroxyurea or were referred for palliative care. There was no access to hypomethylating agents or venetoclax. During the study period, most patients over 60 years were not considered for intensive chemotherapy. Low-risk APL patients were managed with all-trans retinoic acid (ATRA) and idarubicin according to the *Programa Español de Tratamientos en Hematología* (PETHEMA) protocol,[28] and high-risk patients received ATRA, daunorubicin and cytarabine, according to the European APL protocol.[29] There was no access to arsenic trioxide during the study period. The only polymerase chain reaction (PCR) assay for measurable residual disease (MRD) monitoring available during the study period was *PML::RARA* and *BCR::ABL*. There was no access to MRD flow cytometry to guide post-remission treatment. Access to bone marrow transplant was also limited.

During the study period, paediatric patients were treated according to the BFM-2004 standard risk and high-risk treatment protocols, with five blocks of intensive chemotherapy using cytarabine, anthracyclines and etoposide.[30] Acute promyelocytic leukaemia patients received ATRA in addition to the above chemotherapy, in accordance with the BFM-2004 protocol.

Study design

A laboratory-based cross-sectional retrospective study of newly diagnosed AML patients over 3 years, from 01 September 2015 to 31 August 2018, was performed.

Study population

All adult and paediatric patients with a new AML diagnosis confirmed by bone marrow aspirate and trephine (BMAT) performed at TBH during the study period were included. Patients were excluded if they did not have their diagnostic BMAT or their treatment at TBH.

Data collection

Data were collected from the computer databases via the NHLS Central Data Warehouse (CDW). All BMATs that were performed and reported at TBH with a diagnosis of AML were identified. Acute myeloid leukaemia response assessment BMATs and relapsed AML were excluded. The newly diagnosed cases of AML were further assessed on the NHLS laboratory information system (LIS) for the full blood count (FBC) at diagnosis, diagnostic bone marrow findings, cytogenetics, PCR and HIV status. The only molecular studies that were available during the study period were *NPM1* and *FLT3* qualitative PCR. Polymerase chain reaction and cytogenetic results were used to classify the AML

according to WHO-HAEM5 subtypes and according to ELN or BFM-2012 risk stratification, [2,16,23] except for APL, which was risk stratified according to the Sanz criteria.[26] In the absence of genetic data, AMLs were subtyped according to differentiation. Secondary AMLs were classified according to ELN risk stratification, except AML in Down syndrome, which was classified as favourable risk.[31,32,33] For survival data, the hospital electronic administrative system (Clinicom) was used.

Statistical analysis

Statistical analysis was performed on Microsoft Excel and STATA 19 (StatCorp LLC, Texas, US). Descriptive statistics were performed to assess the demographic information. Frequencies were calculated for categorical data. A Pearson's Chi-squared test was used to assess categorical variables. Median and interquartile range (IQR) were calculated for continuous data. A Kruskal–Wallis rank test was performed to compare the ages between categorical variables. To assist with comparison to international literature, the paediatric age group was analysed using both the traditional age stratification of <18 years old, and according to the local age distribution of patients treated by the Paediatric Oncology unit during the study period (≤13 years). Survival analysis was performed using Kaplan–Meier survival curves, with follow-up censored on 01 September 2021. Survival function distributions were compared with a log-rank test. Cox regression analysis with Breslow methods was performed to assess the significance of multiple risk factors on survival and to estimate hazard ratio (HR). A *p*-value of less than 0.05 was considered significant.

Ethical considerations

This study was approved by the Stellenbosch University Human Research Ethics Committee (S21/06/099). A waiver of informed consent was granted, and the study was conducted using retrospective, de-identified data in accordance with relevant regulations.

Results

During the 3-year study period, 216 patients had a BMAT investigation for AML at TBH. There were 114 AML response assessment BMATs and 12 BMATs for relapsed AML, which were excluded. Ninety patients were newly diagnosed with AML.

Demographic and laboratory parameters are provided in Table 1. The majority (86%, 77/90) of patients were adults and 14% (13/90) were children. Older adults ≥60 years made up 39% (30/77) of the adults. The median age of the adults was 54 years (IQR 38–65), and for the children, it was 2 years (IQR 2 years – 7 years) (Table 1). The male-to-female ratio was 1:1.4, with more females than males being diagnosed in the adults, but more males being diagnosed in the children (Table 1). Four of 74 tested patients (5%) were HIV positive.

The season in which AML was diagnosed was evenly spread across summer (22%; 20/90), autumn (26%; 23/90), winter (29%; 26/90) and spring (23%; 21/90) ($p = 0.817$) (Figure 1).

Molecular results and acute myeloid leukaemia subtypes

Karyotype results were available in 68% (61/90), while 22% (20/90) had failed karyotyping and 10% (9/90) had no karyotype requested. The median turn-around-time for karyotype results was 13 days (IQR 7–21). Fluorescence *in situ* hybridisation (FISH) was performed in 50% (45/90) of patients. Cytogenetically normal-acute myeloid leukaemia made up 20% (18/90) of cases. Nucleophosmin protein-1 gene and *FLT3* PCR was performed in 10% (9/90) of patients and was not detected in all cases. Only 63% (57/90) of patients had sufficient cytogenetic and molecular testing for diagnostic subtype and prognostic classification. Despite local protocols recommending mutation testing for patients with CN-AML, only three patients of the 18 patients (17%) with CN-AML had testing.

The majority (88%, 79/90) of cases were *de novo* AML. Acute myeloid leukaemia with defining genetic abnormalities comprised 54% (49/90) of cases, with APL being the most common subtype (21%, 19/90) (Table 1). Acute myeloid leukaemia, myelodysplasia-related (AML-MR) was the second most common subtype, representing 19% (17/90) of cases; this included 13 *de novo* cases and four secondary to MDS (Table 1). The median age of patients with AML-MR was 63 (IQR 36–75). Acute myeloid leukaemia defined by differentiation comprised 38% (34/90) of AML cases. The secondary AML cases included AML secondary to cytotoxic therapy, AML with antecedent haematological disorders and AML with germline predisposition conditions. The latter occurred in patients with Fanconi anaemia and Down syndrome (Table 1). The distribution of AML subtypes was similar in adults and children (Table 1). Patients with AML-MR were significantly older than patients with APL and the other subtypes of AML as a group ($p = 0.026$) (Figure 2a).

Overall survival of acute myeloid leukaemia according to demographics and laboratory parameters

The median OS for all patients was 5 months (IQR 1–50). The 3-year OS was 19% (17/90).

For adult patients (≥18 years), the median OS was 3 months (IQR 1–18) with a 3-year OS of 15% (11/73) (Figure 3b). For adult patients (≥14 years, as per institutional division), the median OS was 4 months (IQR 1–18) with a 3-year OS of 14% (11/77). The median OS for the age group 14 years – 59 years was 7 months (IQR 1–22) with a 3-year OS of 21% (10/47), and the median OS for the older adults ≥60 years was 2 months (IQR 1–5) with a 3-year OS of 3% (1/30) (Figure 3a). Early

TABLE 1: Demographics and laboratory characteristics of patients with acute myeloid leukaemia at Tygerberg Hospital.

Parameter	All					Adult (≥ 14 years)					Children (≤ 13 years)				
	N	Median	IQR	%	*n*	*N*	Median	IQR	%	*n*	*N*	Median	IQR	%	*n*
Age (years)	90	48	24–63	-	-	77	54	38–65	-	-	13	2	2–7	-	-
Older adults (≥ 60)	-	-	-	-	-	30	67	63–75	-	-	-	-	-	-	-
Sex	90					77	-	-	-	-	13	-	-	-	-
Male	-	-	-	42	38	-	-	-	39	30	-	-	-	62	8
Female	-	-	-	58	52	-	-	-	61	47	-	-	-	38	5
HIV positive	74	-	-	5	4	62	-	-	6	4	12	-	-	0	0
Full blood count parameters	90	-	-	-	-	77	-	-	-	-	13	-	-	-	-
White cell count (×10^9/L)	-	9.67	2.59–30.79	-	-	-	8.68	2.37–32.17	-	-	-	15.16	5.71–28.05	-	-
Haemoglobin (g/dL)	-	7.9	6.3–9.6	-	-	-	7.9	6.35–9.7	-	-	-	8.3	5.7–9.6	-	-
Platelets (×10^9/L)	-	42	22–85	-	-	-	40	21–78	-	-	-	95	24–164	-	-
Risk stratification	38	-	-			33	-	-	-	-	5	-	-	-	-
Favourable risk	-	-	-	50	19	-	-	-	21	7	-	-	-	40	2
Intermediate risk	-	-	-	26	10	-	-	-	24	8	-	-	-	40	2
Adverse risk	-	-	-	24	9	-	-	-	55	18	-	-	-	20	1
AML subtypes	90	-	-	-	-	77	-	-			13	-	-	-	-
AML with defining genetic abnormalities	-	-	-	54	49	-	-	-	56	43	-	-	-	46	6
Acute promyelocytic leukaemia with *PML::RARA* fusion, *t*(15;17)	-	-	-	21	19	-	-	-	21	16	-	-	-	23	3
AML, myelodysplasia-related (AML-MR)*	-	-	-	19	17	-	-	-	19	15	-	-	-	15	2
AML with *RUNX1::RUNX1T1* fusion, *t*(8;21)	-	-	-	6	5	-	-	-	5	4	-	-	-	8	1
AML with *KMT2A* rearrangement	-	-	-	4	4	-	-	-	5	4	-	-	-	-	-
AML with *CBFB::MYH11* fusion, inv(16)	-	-	-	2	2	-	-	-	3	2	-	-	-	-	-
AML with *MECOM* rearrangement, inv(3)	-	-	-	1	1	-	-	-	1	1	-	-	-	-	-
AML with *DEK::NUP214* fusion *t*(6;9)	-	-	-	1	1	-	-	-	1	1	-	-	-	-	-
AML defined by differentiation	-	-	-	38	34	-	-	-	38	29	-	-	-	38	5
AML with minimal differentiation	-	-	-	3	3	-	-	-	4	3	-	-	-	-	-
AML without maturation	-	-	-	12	11	-	-	-	13	10	-	-	-	8	1
AML with maturation	-	-	-	8	7	-	-	-	6	5	-	-	-	15	2
Acute myelomonocytic leukaemia	-	-	-	2	2	-	-	-	3	2	-	-	-	-	-
Acute monocytic leukaemia	-	-	-	10	9	-	-	-	10	8	-	-	-	8	1
Acute erythroid leukaemia	-	-	-	2	2	-	-	-	1	1	-	-	-	8	1
Secondary AML	-	-	-	12	11	-	-	-	12	9	-	-	-	15	2
AML post-cytotoxic therapy	-	-	-	3	3	-	-	-	4	3	-	-	-	-	-
MPN transformed	-	-	-	2	2	-	-	-	3	2	-	-	-	-	-
MDS transformed (also included in AML-MR)*	-	-	-	4	4	-	-	-	5	4	-	-	-	-	-
Germline predisposition condition	-	-	-	2	2	-	-	-	-	-	-	-	-	15	2

AML, acute myeloid leukaemia; AML-MR, acute myeloid leukaemia-myelodysplasia related; IQR, interquartile range; MDS, myelodysplastic syndrome; MPN, myeloproliferative neoplasm.
*AML-MR is composed of both *de novo* AML-MR as well as AML-MR secondary to MDS.

mortality (death within 30 days of diagnosis) was 29% (22/77) for all adult patients (14 years – 82 years), 26% (12/47) in the younger adults (14 years – 60 years) and 33% (10/30) for older adults (≥60 years).

For children (<18 years), the median OS was 19 months (IQR 4 – not reached) with a 3-year OS of 35% (6/17) (Figure 3b). In the paediatric patients ≤13 years, the median OS had not been achieved over the study period, and 46% (6/13) were alive at 3 years (Figure 3a). Early mortality was 23% (3/13).

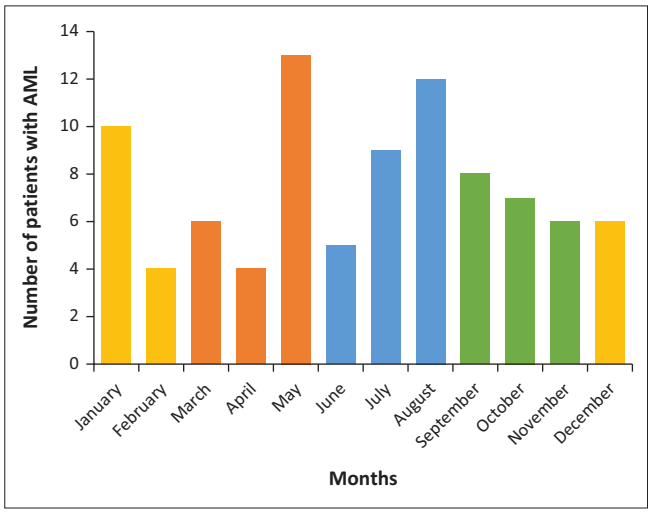
Age had a significant impact on OS, with older patients experiencing lower OS than younger patients (Figure 3a and b). Survival was similar in males and females (p = 0.157) (Figure 3c). Survival was also better in patients with a white cell count (WCC) <50 × 109/L (p <0.001) (Figure 3d) and platelet counts >80 × 109/L (p = 0.004) (Figure 3e).

Overall survival of acute promyelocytic leukaemia and acute myeloid leukaemia-myelodysplasia related

The median OS of APL patients was 11 months (IQR 1–58, n = 19) and the 3-year OS was 37% (7/19) (Figure 3f). The 7-day mortality rate was 11% (2/19), and the 30-day mortality rate was 16% (3/19).

Almost half of the patients (47%, 9/19) had high-risk disease, six patients (32%) were intermediate risk and four patients (21%) were low-risk. The Sanz risk classification did not impact survival (p = 0.951) (Figure 3h).

The median OS of AML-MR patients was 2 months (IQR 1–7, n = 17). The 3-year survival was 6% (1/17). Patients ≥60 years old made up 59% (10/17) of those with AML-MR and would not have been eligible for intensive chemotherapy (Figure 2a).



Note: Seasons are colour coded: summer – yellow, autumn – orange, winter – blue, spring – green.

AML, acute myeloid leukaemia.

FIGURE 1: Months in which acute myeloid leukaemia was diagnosed at Tygerberg Hospital over the period September 2015–August 2018.

Overall survival of acute myeloid leukaemia patients stratified according to risk categories

Only 38 patients had sufficient genetic investigations (karyotype and/or *NPM1* and *FLT3* mutation testing) for ELN or BFM risk stratification (Table 1). The age of the patients with adverse risk was higher than those with favourable risk (p = 0.006) (Figure 2b). The adverse risk group had a significantly increased risk of death (p = 0.003, n = 57) (Figure 3f). In patients <60 years, 36% (9/25) had adverse risk. There was no significant difference in survival between risk categories when only patients <60 years were assessed (p = 0.206, n = 43), although similar trends in survival were observed (Figure 3g).

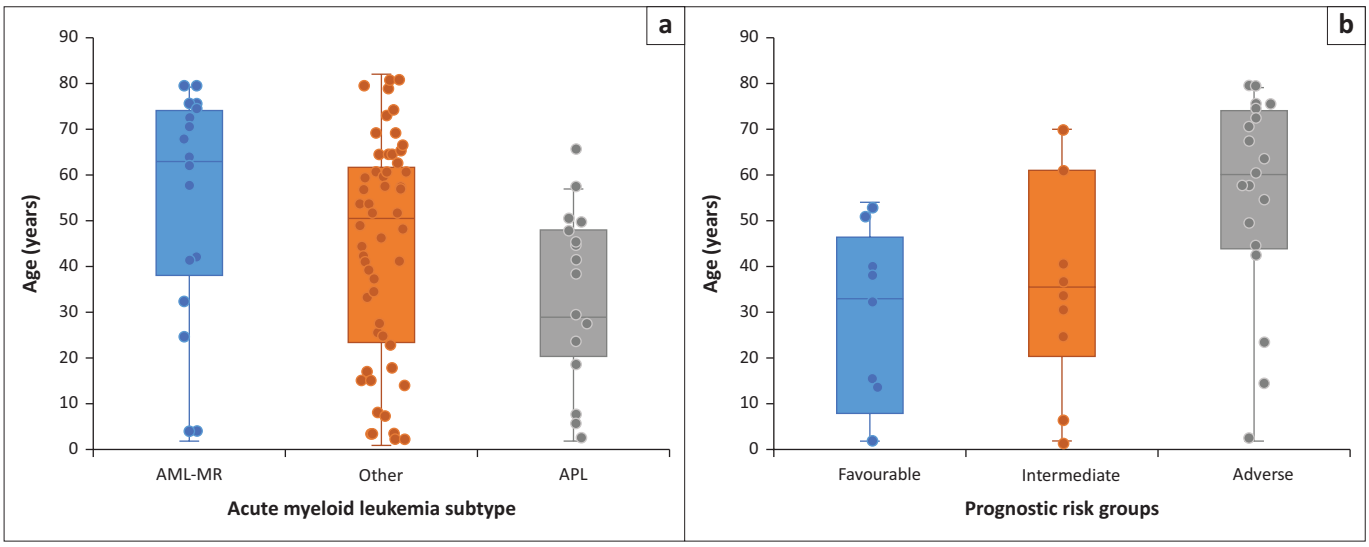
Independent predictors of survival

Increasing age (HR 1.022, 95% CI 1.008–1.037), higher WCC (HR 1.011, 1.005–1.017) and lower platelet count (HR 0.995, 95% CI 0.991–0.999) were independently associated with poor survival (Table 2). Secondary AML and risk stratification were not independent predictors of survival. Cox regression of only the 38 patients with risk stratification also did not reveal risk stratification as an independent predictor of survival, given the strong effect of age (Table 3).

Discussion

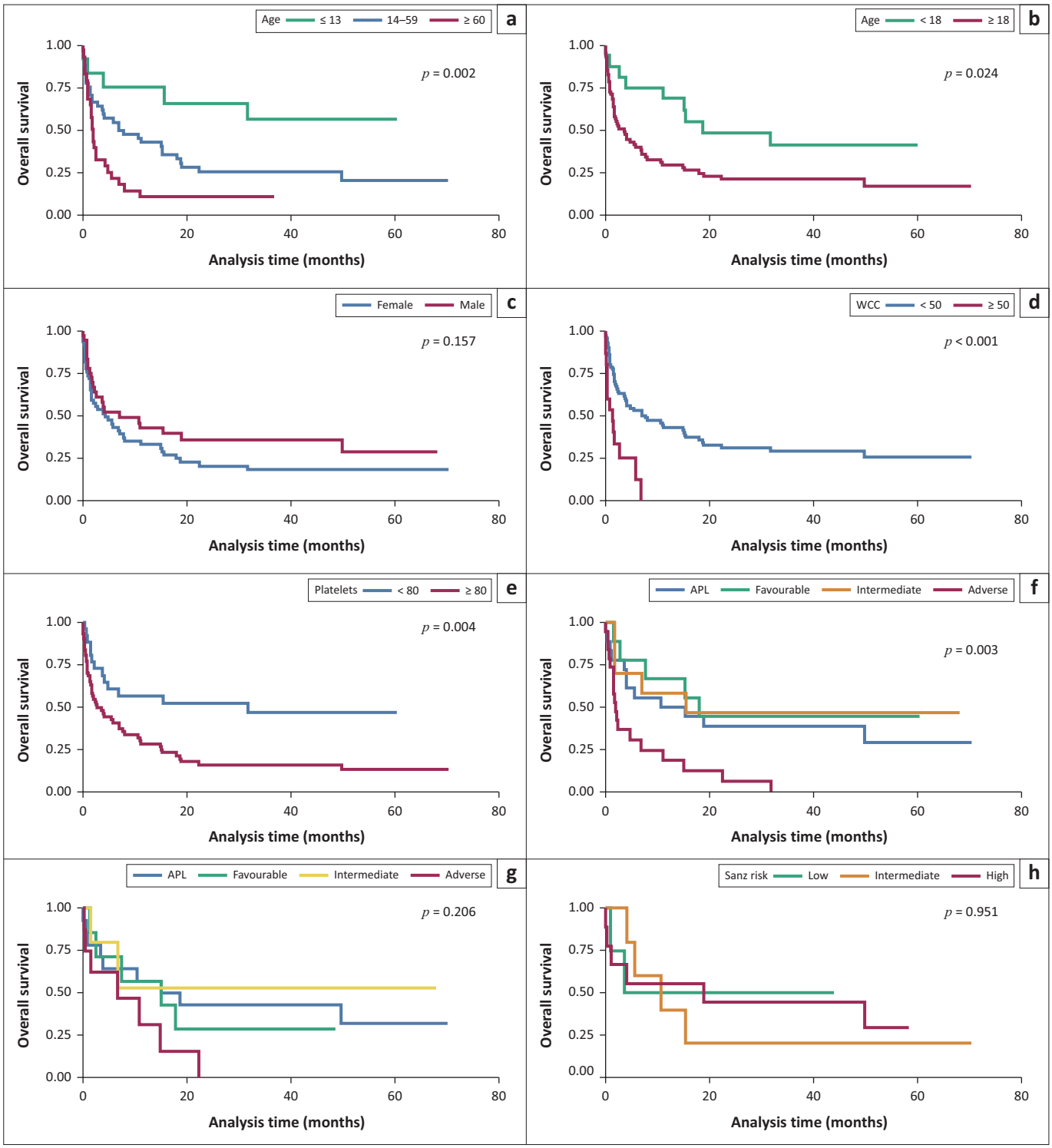
This study has confirmed that the demographics, subtype frequencies and OS of AML were different from those seen in high-income countries.

The median age at diagnosis for adults of 54 years is older than other South African studies, typically in the third decade or



APL, acute promyelocytic leukaemia; AML-MR, acute myeloid leukaemia-myelodysplasia related.

FIGURE 2: Age of patients with acute myeloid leukaemia (a) Acute myeloid leukaemia subtype, namely acute promyelocytic leukaemia, acute myeloid leukaemia-myelodysplasia related and the other subtypes of acute myeloid leukaemia (n = 90) and (b) prognostic risk groups, according to European LeukaemiaNet and International Berlin-Frankfurt-Munster Study Group (n = 39).



APL, acute promyelocytic leukaemia; WCC, white cell count.

FIGURE 3: Overall survival of acute myeloid leukaemia at Tygerberg Hospital according to: (a) age stratified according to clinical management (n = 90), (b) age as per traditional cut-off (n = 90), (c) sex (n = 90), (d) white cell count above and below 50 × 109/L (n = 90), (e) platelet count above and below 80 × 109/L (n = 90) (f) acute promyelocytic leukaemia and prognostic risk classification for all patients (n = 57), (g) acute promyelocytic leukaemia and prognostic risk classification for patients < 60 years old (n = 43) and (h) Sanz risk stratification of patients with acute promyelocytic leukaemia (n = 19).

fourth decade, but still younger than the 6th decade described internationally.[4,5,6,7,10,11,12] The median age of 2 years for children is lower than reported elsewhere in Africa, where the median age is 7 years – 9 years.[34,35,36] The female predominance in the adult patients is similar to a Brazilian study,[37] but contrasts with the male predominance generally reported internationally.[4,5,6,7]

Acute myeloid leukaemia diagnosis was consistent throughout the seasons, unlike reports from Spain and the US.[13,14] It should be noted that the Spanish (n = 26 475) and US (n = 21 570) studies were large; thus, a larger South African study is required to assess whether there is a seasonality of AML in South Africa.

TABLE 2: Independent predictors of survival in acute myeloid leukaemia (N = 90).

Parameter	Hazard ratio	95% CI	*p*-value
Risk category (reference APL)			
Favourable risk	0.691	0.232–2.054	0.506
Intermediate risk	0.639	0.211–1.919	0.423
Adverse risk	1.239	0.524–2.931	0.625
Not classified	1.666	0.765–3.631	0.199
Secondary AML	1.756	0.750–4.114	0.194
Age	1.022	1.008–1.037	0.002
Sex	0.6950	0.401–1.203	0.581
White cell count	1.011	1.005–1.017	< 0.001
Haemoglobin	0.989	0.878–1.114	0.860
Platelet count	0.995	0.991–0.999	0.020

APL, acute promyelocytic leukaemia; AML, acute myeloid leukaemia; CI, confidence interval.

TABLE 3: Independent predictors of survival in acute myeloid leukaemia in patients that were risk stratified (N = 38).

Parameter	Hazard ratio	95% CI	*p*-value
Risk category (reference adverse risk)			
Favourable risk	0.441	0.141–1.374	0.506
Intermediate risk	0.429	0.144–1.267	0.423
Age	1.030	1.008–1.053	0.008
White cell count	1.006	0.996–1.017	0.258
Platelet count	0.999	0.994–1.005	0.899

CI, confidence interval.

The most common subtypes were APL (21%) and AML-MR (19%), which were also seen in another South African study.[10]

Survival rates were similar for males and females, which contrasts with the US, where mortality rates are higher for males.[9]

Survival in AML has improved over the years with increased understanding of AML biology and access to treatment. The median OS of adults (>18 years) at our institution was 3 months, which is shorter than the 8.9 months reported in a French population-based study of adult patients diagnosed between 1980 and 2004.[8] In a US study of patients from 2001 to 2018, the 3-year relative survival for patients 20 years – 39 years old was 63.4% and for 40 years – 59 years old was 46.9%, superior to the 21% 3-year OS of adult patients (14 years – 60 years) in our study.[9] Similarly, in our study, the median OS of adults 14 years – 60 years was 7 months, and in older adults (≥60 years) was 2 months, which poorer than a study from Brazil investigating AML patients from 2003 to 2009, where patients ≤60 years had a OS of 12.4 months and those >60 years had an OS of 8.2 months.[38] A more recent Brazilian study of patients from 2013 to 2020 showed a median OS of 38.8 months and a 5-year OS of 39.4%.[37]

Despite investigating patients from around the same time period, a study of patients in Romania receiving intensive treatment from 2015 to 2021 showed an OS of 8.7 months, highlighting the variability of AML outcomes across geographies.[39] The early mortality of our adult patients (14 years – 60 years) of 26% was also higher than the 17.3% in the Romanian study.[39] The median OS of our adult patients was better than the 2 months seen in adult AML patients in Uganda,[40] and the crude median OS of 1.75 months in a Johannesburg laboratory-based South African study.[10] Importantly, patients at our facility who were >60 years old and/or not fit for intensive chemotherapy did not have access to hypomethylation agents. These agents have been shown to improve OS from 2 months if untreated, to 6 months if treated, with the greatest benefit seen in those under 70 years achieving a median OS of 10 months.[41]

In paediatric patients (<18 years), the median OS was 19 months, which was better than other African studies (2.6 months – 4 months), and similar to an Indian study of patients <18 years (14.6 months).[34,42,43] Compared to European patients ≤14 years with a 5-year relative survival of 70.5%,[44] the 3-year OS of 46% for our paediatric patients ≤13 years highlights that there are several obstacles faced in a resource limited setting to achieve improved outcomes in paediatric AML. Inferior outcomes of paediatric AML in low-income and middle-income countries have been mainly attributed to abandonment of treatment, early death, treatment-related mortality and low salvage rates after relapse.[45,46]

Further studies are required in the South African public sector in both adult and paediatric patients, to assess the reasons for the inferior OS. These may include high rates of infection-related mortality, limited access to intensive care and blood product support, barriers to care for patients living in rural areas, a lack of access to comprehensive diagnostic testing and MRD monitoring, as well as limited availability of novel therapeutic agents and stem cell transplantation for older patients in the public sector.

The OS of APL appears to vary significantly across South Africa. The proportion of high-risk APL between studies may account for some of the variation in outcomes between centres. While the median OS in our study was 11 months with a 3-year OS of 37% (47% high-risk, n = 19), a Johannesburg study showed a crude median OS of 1.5 months (51.2% high-risk, n = 43), and a study from Groote Schuur Hospital in Cape Town reported a 3-year OS of 76.5% (39% high-risk, n = 69), the latter having similar survival to that of high-income countries (28% high-risk, n = 1095).[10,47,48] Our study showed a 7-day mortality rate of 13% and a 30-day mortality rate of 19%, which was higher than the 7% and 13%, respectively, seen at the other Cape Town centre, but lower than the 18.5% and 33.3%, respectively, seen in a Bloemfontein study (56% high-risk, n = 27) and the 31.1% and 46.9%, respectively, seen in the Johannesburg study.[10,47,49] A larger study with a more in-depth analysis of APL at our centre is required to assess the high early death rate, including factors such as timely diagnosis and initiation of supportive care, delays in administering the first dose of ATRA because of transport issues from rural areas, and the availability of blood product support at peripheral hospitals to manage the associated coagulopathy.

In our study, age was an important independent risk factor for OS. The prognostic significance of risk stratification was not fully appreciated compared to the significant impact of

age on survival. It is worth noting that the median age of the adverse risk group was older than that of the intermediate- and low-risk groups.

This highlights that older patients are not only more likely to have a generally poorer performance status and not receive intensive chemotherapy, but also have more adverse genetic abnormalities, which contribute to a worse prognosis.[50] That being said, addressing cost barriers and expanding access to effective therapies, such as venetoclax and hypomethylating agents may improve outcomes for this group of patients. The prognostic risk stratification would also likely have been adjusted if an next-generation sequencing (NGS) myeloid was available during the study period. In addition, high WCC was found to influence OS, which has been previously reported.[39,51,52]

The prognostic significance of pretreatment platelet count is less robust, with some studies showing improved survival at low platelet counts, while others show better survival at higher platelet counts, as seen in our study.[53,54,55]

The small number of adult AML patients with an available karyotype and/or molecular testing affected the subtype classification of AML and risk stratification, with only 57 patients and 38 patients with sufficient data, respectively. We did not have any patients that had AML with *NPM1* mutation, but this may be attributed to suboptimal testing practices, rather than absence of this subtype at our facility. The incompletely investigated patients with CN-AML may be attributed to the karyotype results usually only being available after induction chemotherapy is complete. We recommend establishing an algorithmic approach for the work-up for an AML patient so that an inclusive panel of mutations can provide more comprehensive insights into the effect that AML genetics has on outcome in South Africa. Current practice at our institution has since evolved with the implementation of more comprehensive risk stratification of patients, facilitated by the availability of a myeloid NGS panel.

Limitations

There were too few paediatric patients with AML over the study period for meaningful survival subanalysis.

Being a laboratory-based study, the reasons for inferior outcomes, including the high number of early deaths in adults, especially APL patients, could not be elucidated. A clinically focussed study is needed to further elucidate the contribution of clinical presentation and management aspects on outcomes.

Conclusion

The age at diagnosis of AML in this public sector patient cohort was younger than reported in international studies, and the mild female predominance contrasts with international studies. The OS was shorter than internationally reported. While age and AML genetic risk stratification are important determinants of outcome internationally, we found that age, WCC and platelet count were the only independent risk factors for OS in our study. Even though our AML patients were younger and therefore a higher proportion should theoretically be fit for chemotherapy, the OS was lower than internationally. This highlights the need for improved access to affordable diagnostic, monitoring and treatment modalities in the South African context to afford better clinical outcomes. Management should include access to standard of care treatment for fit and unfit patients in the public sector. However, this is not always cost-effective in a resource limited setting. Further studies focusing on clinical parameters and treatment specifics are required to fully elucidate the reasons for the inferior outcome in our setting. Evaluation of outcomes must also be revisited considering the recent change in practice at the institution, with increasing access to a diagnostic myeloid NGS panel as well as MRD flow cytometry and an expanded repertoire of MRD PCR tests, for improved risk stratification, response assessments and earlier transplant referral.

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Competing interests

The authors, Keshanya Moodley, Erica-Mari Nell, Fatima B. Fazel, Anel van Zyl, Leilah Schoonraad and Zivanai C. Chapanduka, declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRediT authorship contribution

Keshanya Moodley: Conceptualisation, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Visualisation, Writing – original draft, Writing – review & editing. Erica-Mari Nell: Conceptualisation, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualisation, Writing – review & editing. Fatima B. Fazel: Writing – review & editing. Anel van Zyl: Writing – review & editing. Leilah Schoonraad: Writing – review & editing. Zivanai C. Chapanduka: Conceptualisation, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Visualisation, Writing – original draft, Writing – review & editing. All authors reviewed the article,

contributed to the discussion of results, approved the final version for submission and publication, and take responsibility for the integrity of its findings.

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Data availability

The data that support the findings of this study are not openly available because of ethical considerations and are available from the corresponding author, Keshanya Moodley, upon reasonable request.

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