

UNC Lineberger Cancer Network
RESEARCH TO PRACTICE Live Webinar
November 16, 2022

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1

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UNC Lineberger Cancer Network

RESEARCH TO PRACTICE

November 16, 2022

Acute Myeloid Leukemia with Myelodysplasia-Related Changes (AML-MRC): An Evolving Diagnostic and Therapeutic Paradigm



Joshua F. Zeidner, MD



6

OUR PRESENTER



Joshua F. Zeidner, MD

Joshua F. Zeidner, MD, is an Associate Professor of Medicine at the University of North Carolina School of Medicine, Lineberger Comprehensive Cancer Center.

Dr. Zeidner is the inaugural Director of Clinical Cancer Research Commercial Integration at Lineberger Comprehensive Cancer Center and serves as the Section Chief of Leukemia Research and Associate Chief of Research within the Division of Hematology at University of North Carolina.

Dr. Zeidner's research focuses on drug development, early phase clinical trials, and innovative therapeutic strategies in acute myeloid leukemia and myelodysplastic syndromes with a particular interest in immunotherapy and apoptotic pathways.

He has designed and developed multiple Phase III studies in AML and serves as Principal Investigator on a multitude of cutting edge studies in AML and MDS.

7

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Acute Myeloid Leukemia is a type of cancer of the blood and bone marrow with excess immature white blood cells.



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8

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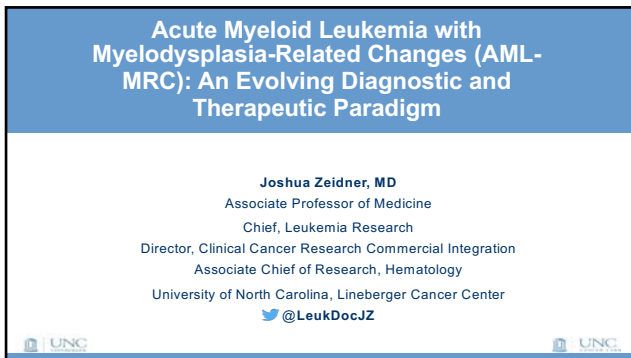
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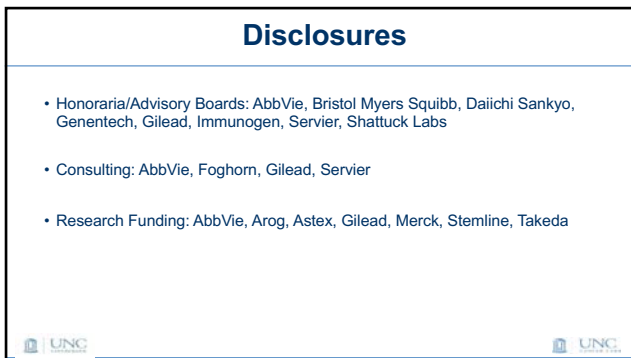
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10





11



12

Objectives



- To describe the diagnostic work-up and criteria of AML
- To describe the different subclassifications of AML based on the World Health Organization (WHO) and International Consensus Classification (ICC)
- To list prognosis, treatment options and emerging therapies for AML-MRC

13

Case #1



- A 66 year old male with a past medical history significant for hypertension and well controlled diabetes mellitus-2 presents to his Primary Care Physician after gradual worsening symptoms of fatigue, lethargy, anorexia, and weight loss over 1-2 months.
- CBC with differential performed revealing:
 - WBC: 2.2x10⁹/L, Hemoglobin: 7.8 g/dL, Platelets: 31x10⁹/L
 - Absolute Neutrophil Count (ANC): 0.6x10⁹/L
- Peripheral blood smear reviewed revealing dysplastic granulocytes and immature cells
- Referred to Hematologist/Oncologist and bone marrow biopsy performed
 - Hypercellular marrow (>95%) with 28% myeloblasts
 - Flow cytometry reveals myeloid immunophenotype- CD34, CD33, CD13, MPO positive

14

Case #1 Question

- Despite increasing symptoms over the past 1-2 months, patient has a good ECOG PS (ECOG PS = 1).
- No evidence of tumor lysis syndrome or other complications
- **What is the best next step in the management of this patient?**
 - A) 7+3 induction chemotherapy
 - B) Azacitidine + Venetoclax
 - C) CPX-351 induction therapy
 - D) Provide transfusion support and supportive care while awaiting further diagnostic information

15

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What is the best next step in the management of this patient?

- 7+3 induction chemotherapy
- Azacitidine + Venetoclax
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16

What is AML?

Hematopoiesis in humans

- Clonal proliferation of myeloid precursors (i.e., myeloblasts)
 - Reduced capacity for differentiation
 - Reduced capacity for cell death

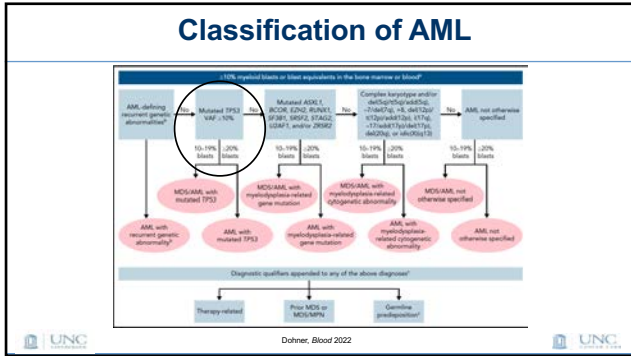
17

Diagnosis of AML

- Has evolved -> Increasingly incorporating genomic abnormalities into definition
- Traditionally defined as $\geq 20\%$ myeloblasts in PB or BM
 - Dx dependent on immunophenotype of myeloblasts by flow cytometry
 - Updated 2022 criteria (WHO & ICC) recognize the subjectivity of blast %
 - MDS/AML category of 10-19% blasts (ICC)

WHO Classification	ICC/ELN Criteria
Acute myeloid leukaemia with defining genetic abnormalities Acute promyelocytic leukaemia with PML-RARA fusion Acute myeloid leukaemia with RUNX1-RUNX1T1 fusion Acute myeloid leukaemia with CBF360911 fusion Acute myeloid leukaemia with DEKAF1214 fusion Acute myeloid leukaemia with FUS1240174 fusion Acute myeloid leukaemia with BCR-ABL1 fusion Acute myeloid leukaemia with KMT2A rearrangement Acute myeloid leukaemia with MECOM rearrangement Acute myeloid leukaemia with NUPR1 rearrangement Acute myeloid leukaemia with MLL2 rearrangement Acute myeloid leukaemia with CBFB rearrangement	AML with recurrent genetic abnormalities (requiring $\geq 10\%$ blasts in BM or PB)* • APL with t(15;17)(q24.1;q21.2)/PML-RARA • AML with t(8;21)(q22;q22.1)/RUNX1-RUNX1T1 • AML with inv(16)(p13.1;q22) or t(16;16)(p13.1;q22)/CBFB-MYH11 • AML with t(9;11)(p21.3;p23.3)/MLL2-KMT2A • AML with t(6;9)(p22;q34.1)/DEK-NUP214 • AML with inv(3)(q21.3;q26.2) or t(3;3)(q21.3;q26.2)/GATA2, MECOM/ELN • AML with other rare recurring translocations • AML with mutated NPM1 • AML with in-frame b2ip mutated CEBPA • AML with t(9;22)(q34.1;q11.2)/BCR-ABL1

18



19

TP53 Mutated AML

- TP53 mutation- distinct genomic entity recognized by WHO and ICC
- Approximately 10% of MDS/AML- highly associated with complex karyotype
- Not all TP53 mutations created "equal"
- **Biallelic/Multi-Hit**
 - ≥ 2 TP53 mutations, mutation + loss of 17p, LOH at 17p, and/or high VAF (>50%)
 - Outcomes worse in MDS
- Harmonization of MDS ($\geq 10\%$ blasts) and AML w/ TP53 mutations
 - ICC category of MDS/AML w/ TP53 mutation- equally poor outcomes

Weinberg, Blood Adv 2022

20

TP53 Mutated AML- Poor Outcomes w/ Aza/Ven

- High unmet need- poor outcomes w/ intensive chemo and Aza/Ven
- Identification of TP53 mutation critical for tailoring Tx
- Clinical trials imperative for TP53 mut MDS/AML

Polyesa, Clin Cancer Res 2022

21

Genomic Classes of AML

Table 1. Proposed Genomic Classification of Acute Myeloid Leukemia (AML)

Genomic Subgroup	Frequency in the Study Cohort (N = 1548)	Most Frequently Mutated Genes*
AML with NPM1 mutation	n = 47 patients (3%)	gene (3) NPM1 (100), DNMT3A (54), FLT3 ^{ITD} (39), NRAS (18), TP53 (10), IDH1 (10)
AML with mutated chromatin, RNA-splicing genes, or both	275 (18%)	RUNX1 (39), MLL ^{WT} (25), SMYD2 (22), DNMT3A (20), ASXL1 (17), STAG2 (16), NRAS (14), TET2 (15), FLT3 (12)
AML with TP53 mutations, chromosomal aneuploidy, or both	199 (13%)	Complex karyotype (32), -5q (27), -7p (14), TP53 (14), -17p (13), -17q (11), -13Q (11), -4,8q (10)
AML with inv(16)(p11.3q22) or t(8;21)(p11.3;q22), CEBPA ^{WT}	81 (5%)	inv(16) (100), NRAS (51), -4,8q (14), +2 (14), WT (10), FLT3 ^{ITD} (5)
AML with biallelic CEBPA mutations	66 (4%)	CEBPA ^{mut/mut} (100), NRAS (30), WT (21), GATA2 (20)
AML with t(11;17)(q23;q23), PRK8-RARA	40 (3%)	t(11;17) (100), FLT3 ^{ITD} (33), WT (17)
AML with t(10;12)(p12;p21), RUNX1-RUNX1T1	40 (3%)	RUNX1 (100), KIT (10), -9p (9), -9q (8)
AML with MLL fusion genes, t(9;11)(p24;q23)	44 (3%)	MLL ^{WT} (100), NRAS (23)
AML with inv(3)(q21q26.2) or t(3;3)(q21;q26.2), GATA2, MECOM ^{WT}	20 (1%)	inv(3) (100), -7 (8), KRAS (30), NRAS (15), PTEN (10), FLT3 (15), NUP210 (15), SF3B1 (11)
AML with CHD2 ^{WT} mutations and no other class-defining lesions	18 (1%)	IDH2 ^{WT} (100), DNMT3A (67), -4,8q (17)
AML with t(8;21)(p11.3;q22), DEK-NUP214	13 (1%)	WT (100), FLT3 ^{ITD} (80), KRAS (20)
AML with driver mutations but no defined class-defining lesions	168 (11%)	FLT3 ^{ITD} (39), DNMT3A (24)
AML with no detected driver mutations	52 (3%)	
AML meeting criteria for ≥2 genomic subgroups	56 (4%)	

*Papaemmerll, N Engl J Med 2016

• Subgroup associated with older age, worse prognosis and features of AML-MRC

25

Updated AML-MRC Classification in 2022

- Now termed AML-MR (WHO), AML w/ MDS-related cytogenetics or AML w/ MDS-related gene mutations (ICC)
 - No longer includes multilineage dysplasia as diagnostic criteria
- Both WHO and ICC incorporate mutations into criteria for AML-MRC

Table 8. Cytogenetic and molecular abnormalities defining acute myeloid leukaemia, myelodysplastic syndrome

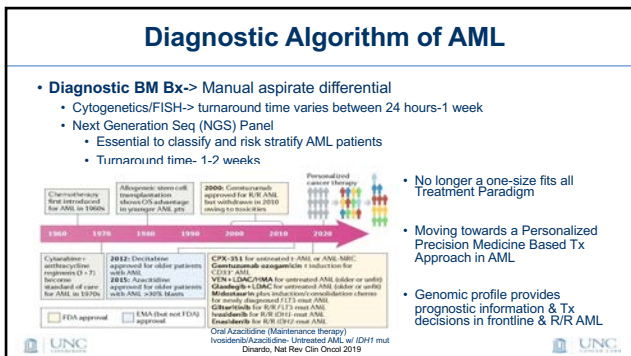
Defining cytogenetic abnormalities
 Complex karyotype (≥3 abnormalities)
 Ig deletion or loss of Ig due to t(14;18) translocation
 Monosomy 7, 8q deletion, or loss of 9q due to unbalanced translocation
 +3q deletion
 +1q deletion or loss of 4p due to unbalanced translocation
 Monosomy 9 or 13q deletion
 +7q deletion or loss of 7p due to unbalanced translocation
 trisomy 12q

Defining genetic mutations
 DNMT3A
 IDH1
 IDH2
 FLT3
 TET2
 NRAS
 KRAS
 NRXN1

Khoury, Leukemia 2022; Arber, Blood 2022

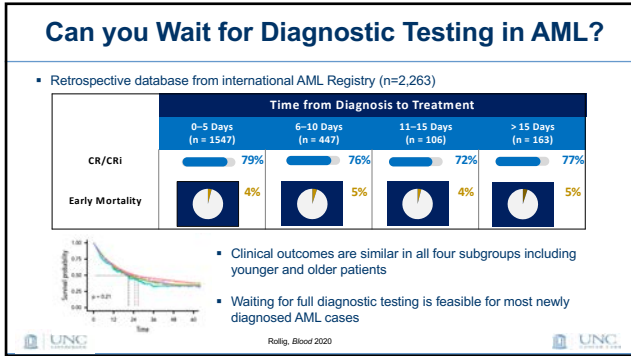
- ICC also includes +8 and del(20q) cytogenetics & RUNX1 mutation as MDS-defining
- Critical to obtain all diagnostic information-> Tx decisions based on classification
- AML-MRC defining mutations now considered adverse-risk by ELN

26



- No longer a one-size fits all Treatment Paradigm
- Moving towards a Personalized Precision Medicine Based Tx Approach in AML
- Genomic profile provides prognostic information & Tx decisions in frontline & R/R AML

27



28

Question #2- Case

- 66 yo M with newly diagnosed AML
- Cytogenetics reveal monosomy 7
- NGS mutational panel: ASXL1 mutation

What is the most accurate ELN Risk Group and WHO Classification for this patient?

- Favorable-risk; AML with MDS-Related Changes
- Intermediate-risk; AML without maturation
- Adverse-risk; AML Not Otherwise Specified
- Adverse-risk; AML with MDS-Related Changes

29

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What is the most accurate ELN Risk Group and WHO Classification for this patient?

- Favorable-risk; AML with MDS-Related Changes
- Intermediate-risk; AML without maturation
- Adverse-risk; AML Not Otherwise Specified
- Adverse-risk; AML with MDS-Related Changes

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30

Question #3- Case

What is the optimal frontline regimen for this patient?

- A) 7+3 induction therapy
- B) CPX-351 induction therapy
- C) Azacitidine + Venetoclax
- D) Hypomethylating agents alone
- E) Clinical Trial

31

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What is the optimal frontline regimen for this patient?

7+3 induction therapy

CPX-351 induction therapy

Azacitidine + Venetoclax

Hypomethylating agents alone

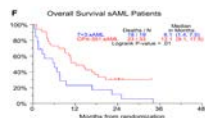
Clinical Trial

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32

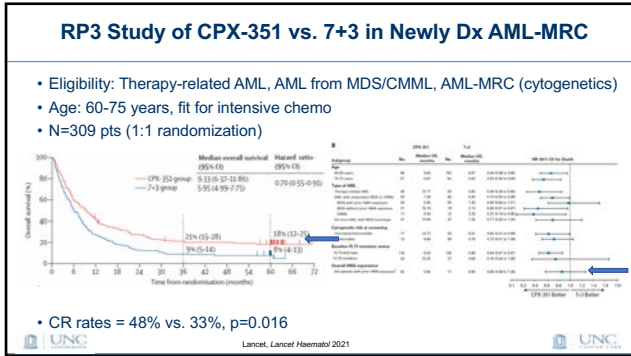
CPX-351

- Liposomal formulation of cytarabine and daunorubicin
- Initial activity & safety noted in newly diagnosed older AML pts
- **Randomized Phase 2 Study:** CPX-351 vs. 7+3 in newly diagnosed AML pts 60-75 years
 - Not restricted to specific risk groups
 - CR rates = 67% vs. 51%, p=0.07
 - Median OS = 14.7 months vs. 12.9 months; lower 60-day mortality with CPX-351

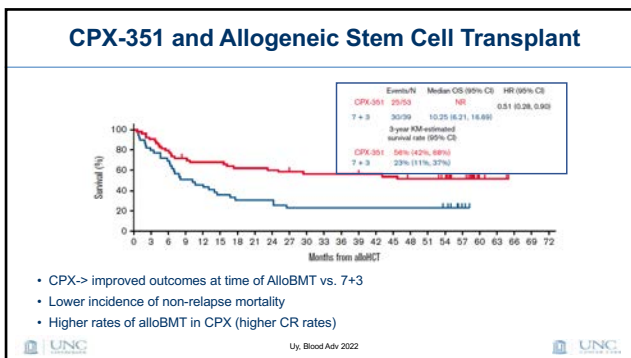


CR rates in Secondary AML: 58% vs. 32%

33



34



35

CPX-351 SOC for AML-MRC

- CPX-351 FDA-approved for management of AML-MRC, therapy-related AML, or AML from preexisting MDS/CMML in 2017
- No age restriction by label but landmark study only conferred benefit in 60-75 yrs.
 - Best outcomes in pts who achieve CR followed by alloBMT
- Studies ongoing in other pt populations
- 7+3 not a useful comparator- dismal outcomes in control group
 - Unclear how CPX compares with Azacitidine + Venetoclax- NCT04801797 (PI: Fathi, MGH)
- Evolving definition of AML-MRC-> which genomic subgroups truly benefit from CPX?
 - TP53 mutations do not appear to benefit from CPX
- CPX moves the needle slightly- outcomes still poor in AML-MRC

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36

How Do We Improve Outcomes in AML-MRC?




37



Immune System is Dysfunctional in AML

- Multiple immune aberrations exist in AML at Dx-> immune suppression, exhaustion, and senescence
 - Dysfunctional T effector cells
 - Increased expression of coinhibitory molecules and decreased expression of co-stimulatory genes
 - Increased Tregs
 - Dysfunctional and deficient NK cells
 - Tolerogenic dendritic cells and antigen presenting cells

A Memory subsets

Memory "like" subsets

- ↑ % of senescent and exhausted T cells at diagnosis-> functionally impaired
- Dysfunctional immune state reversible in CR but persists in pts without response to induction chemo



Ustun, Blood 2011; Kanakry, Blood 2010; Kraus, JCI Insight 2018

38

Early Lymphocyte Recovery (ELR)-> Enriched for Tregs

- 20 AML pts undergoing intensive induction therapy
- Serially assessed for T cell subsets during ELR (WBC >0.2x10⁹/L above nadir)
- Predominance of actively proliferating (high Ki67) Tregs during ELR irrespective of response

• **Hypothesis:** Immune modulation at the time of ELR after induction chemo may mitigate dysfunctional immune phenotype & improve clinical activity of chemo

Kanakry, Blood 2011

39

Pomalidomide

- Pomalidomide- 2nd generation IMiD approved for multiple myeloma

- IMiD's = protean immune-stimulation
- Potentiates co-stimulation of T cells
- Down-regulates co-inhibitory receptors
- Inhibits Tregs
- Enhances NK cell activity
- Inhibits angiogenesis

Hypothesis: Pomalidomide at ELR will mitigate immune dysfunctional phenotype and increase clinical activity of induction chemotherapy

Gandhi AK, Br J Haematol 2013; Zeidner JF, Curr Drug Tar 2017

40

NCI-9524: Phase 1 Study of Induction Chemo Followed by Pomalidomide in Newly Dx AML

- Eligibility: Newly Dx AML or HR-MDS (>10% blasts)
- 18-65 years, excluded favorable-risk cytogenetics

Zeidner, Leukemia 2020

41

Consort Diagram

Zeidner, Leukemia 2020

42

Patient Characteristics

Patient Characteristics	High-Risk MDS (N=4)	AML (N=39)	Total (N=43)
Age- Median (Range)	50 (35-63)	54 (21-65)	54 (21-65)
Age ≥60 Years	1 (25%)	11 (28%)	12 (28%)
Male/Female	2/2	16/23	18/25
BM Blast %- Median (Range)	17% (15-18%)	55% (11-95%)	54% (11-95%)
Peak WBC- Median (Range)	3.1 (0.9-5.3)	12.7 (1.0-227.3)	6.1 (0.9-227.3)
Secondary AML	N/A	14 (36%)	14 (33%)
AML w/ MDS-Related Changes	N/A	13 (33%)	13 (30%)
SWOG Cytogenetic Risk			
Favorable	0	0	0
Intermediate	1 (25%)	23 (59%)	24 (56%)
Unfavorable	3 (75%)	14 (36%)	17 (40%)
Unknown	0	2 (5%)	2 (5%)
NPM1 mutations	0	8 (21%)	8 (19%)
FLT3-ITD Mutations	0	4 (10%)	4 (9%)

43

Safety Data

- Median time to Pom = 21 days (Range: 15-30 days)
 - Cohort 2: DLTs: 8 mg x 21 days = Grade 3 hepatitis and Grade 4 respiratory failure
 - MTD = 4 mg x 21 days
- Most common toxicities = rash (16%), hepatitis (14%), mucositis (14%)
- 14 pts (33%) discontinued Pom early
- Median time to full hematologic recovery 38 days

Adverse Event	2 mg x 15 days (n=5)	4 mg x 10 days (n=5)	6 mg x 10 days (n=7)	2 mg x 21 days (n=25)	8 mg x 21 days (n=5)
Infectious					
Fever		1	3	5	1
Neutropenia					
Lung Infection				1	
Sepsis					
Electrolytes					
Hypokalemia				1	
Hepatic					
ALT elevation				1	1
AST elevation					
Pulmonary					
Hypoxia				1	1
Respiratory Failure					
Renal					
AKI				1	
General					
Fatigue				1	1
Maculopapular Rash				5	

44

Clinical Activity of AcDVP16 + Pomalidomide

Response Characteristics	High-Risk MDS	AML	Overall
CR	3/4 (75%)	28/39 (72%)	31/43 (72%)
CRi	0	2/39 (5%)	2/43 (5%)
CR + CRi	2/4 (50%)	30/39 (77%)	33/43 (77%)
MRD negative CR/CRi	1/4 (25%)	18/39 (46%)	19/43 (44%)
Secondary AML	N/A	10/14 (71%)	10/14 (71%)
AML with MDS-Related Changes	N/A	11/13 (85%)	11/13 (85%)
<60 years	2/3 (67%)	21/28 (75%)	23/31 (74%)
≥60 years	1/1 (100%)	9/11 (82%)	10/12 (83%)
SWOG Cytogenetics Risk			
Favorable	N/A	N/A	N/A
Intermediate	7/7	16/23 (70%)	17/25 (68%)
Unfavorable	2/3 (67%)	12/14 (86%)	14/17 (82%)
Unknown	N/A	2/2 (100%)	2/2 (100%)
Allogeneic SCT	3/4 (75%)	23/39 (59%)	26/43 (60%)
60 day mortality	0	1/39 (3%)	1/43 (2%)

45

Outcomes Compared with Historical Controls

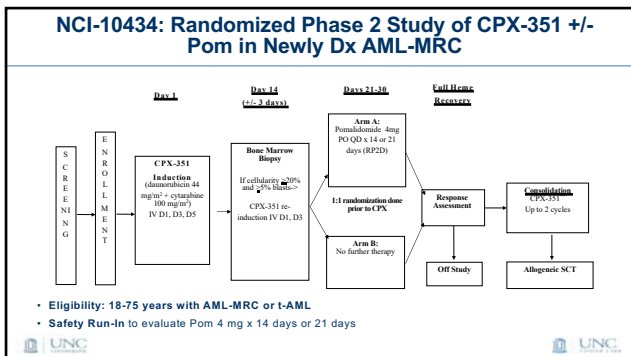
CR Subsets	Historical Controls (AcDVP16) ¹	AcDVP16 + Pom ²
Median Age	52 (20-74)	54 (21-65)
Overall CR/CR1	205/301 (68%)	30/39 (77%)
Age ≥60 years	45/79 (57%)	9/11 (82%)
Secondary AML	51/96 (53%)	10/14 (71%)
Cytogenetics		
Intermediate	133/180 (60%)	16/23 (70%)
Unfavorable	49/94 (52%)	12/14 (86%)
Non-Favorable	182/274 (66%)	30/39 (77%)
Median OS	17.2 months	33.8 months
Median DFS	15.0 months	27.1 months
Unfavorable Cytogenetics		
Median OS	8.2 months	19.7 months
Median DFS	9.2 months	8.2 months

46

Summary of Phase 1 Results

- Pomalidomide is safe and feasible after induction therapy for AML
 - MTD = 4 mg x 21 days at ELR
- Addition of Pom to induction therapy-> encouraging clinical activity
 - CR rates = 77%, Median OS = 33 months w/o appreciable increase in early mortality
 - Compares favorably with historical controls of AcDVP16 induction w/o Pomalidomide
- Correlates: Pom-> Robust decrease in Aiolos expression, promoted T cell differentiation, proliferation and cytokine production
 - Pom may augment immune activation and abrogate T cell exhaustion/senescence after induction chemo



47



48

NCI-10434: Randomized Phase 2 Study of CPX-351 +/- Pom in Newly Dx AML-MRC



- 18-75 years with newly diagnosed AML ($\geq 20\%$ blasts in blood or BM)
- Must meet following criteria:
 - Therapy-related AML
 - AML-MRC- incorporating 2022 WHO/ICC Guidelines with cytogenetics and/or mutations
 - Previous history of myeloid malignancy
- No prior treatment for AML other than hydroxyurea
- Fit for intensive chemo- adequate organ function
 - EF $>50\%$, AST/ALT $<5 \times \text{ULN}$, total bilirubin $<1.5 \times \text{ULN}$, Creatinine clearance >30 ml/min

49

NCI-10434: Statistical Design



- **Primary Endpoint(s):**
 - 1) To establish recommended phase II dose of pomalidomide after CPX-351 induction
 - 2) To compare overall CR rates between CPX-351 + Pom vs. CPX
 - Null hypothesis: 48% CR/CRi rate with CPX-351
 - Alternative hypothesis: 77.3% CR/CRi rate with CPX-351 + Pom
 - 80% Power with one-sided type 1 error rate = 5%
 - N= 78 pts (1:1 randomization)
- **Trial Design:**
 - 1st stage = 16 pts in each arm- trial may stop for futility if one-sided p >0.52
 - Feasibility Analysis
 - Continuous Monitoring for Toxicity

50

NCI-10434: Translational Correlates



- **Biomarker** analysis to assess for predictors of response to Pom
 - Comprehensive NGS mutational panel on all pre-treatment BM samples (Foundation One Heme)
 - Aiolos- transcription factor selectively ubiquitinated by Cereblon during Pom administration
 - To assess whether Aiolos expression in PB and BM at baseline associated w/ CR to CPX-351 + Pom
 - Immune correlates of response by flow cytometry
 - To assess whether pre-treatment expression of T cell subsets in PB and BM associated w/ CR to CPX-351 + Pom
- **MRD Analysis**
 - All pts will have uniform flow cytometry MRD at response (Hematologics)
 - DNA Seq at response to assess depth of CR w/ CPX-351 + Pom vs. CPX-351

51

AML-MRC Future Directions



- **Can addition of Venetoclax improve outcomes in AML-MRC?**
 - Aza/Ven SOC for older unfit AML
 - Older fit AML pts appear to have similar outcomes b/w CPX and Aza/Ven
 - Intensive chemo (FLAG-IDA) + Ven promising induction backbone
- **Optimal Treatment for AML-MRC after previous exposure to HMA's**
 - No SOC, intensive chemo-> dismal outcomes
 - Aza/Ven excluded pts w/ previous HMA's
 - TAGALONG Study: Phase II study of Tagraxofusp +/- Azacitidine (NCT05442216)
- **Optimal Treatment for AML-MRC <60 years?**
 - Limited data of CPX in <60 years
 - Real World Data suggests favorable outcomes w/ CPX
 - NCRI AML19- FLAG-IDA vs. CPX in newly diagnosed adverse-risk AML

52


Conclusions

- Definition of AML has evolved to incorporate genomics-> more refined subclassifications
- AML treatment armamentarium expanding
 - No longer a one-size fits all Tx paradigm
 - Moving closer to a Precision-Medicine based Individualized Treatment Approach
- AML-MRC- now includes both cytogenetics and molecular mutations
 - Critical to obtain diagnostic information (cytogenetics, FISH, NGS) prior to Tx initiation
- CPX-351 is SOC for fit AML-MRC pts-> outcomes are still poor
- Clinical trials are imperative for AML



 

53

Acknowledgments



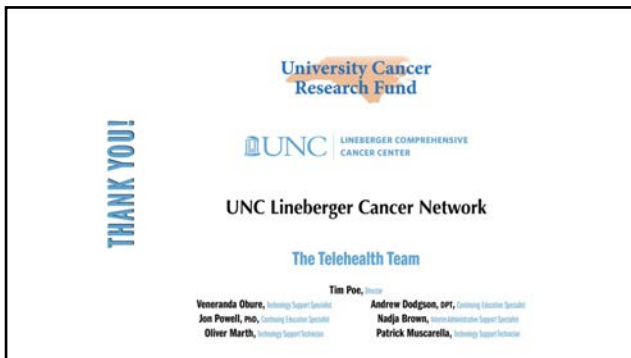
- Mentorship- Drs. Judy Karp, Ivana Gojo, Leo Luznik, Jon Serody
- UNC & Johns Hopkins Leukemia Groups
- Questions: Email: Joshua_Zeidner@med.unc.edu
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54



55



56



57

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58

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59

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60