

/DFWDWH 'HK\GURJHQDVH /GK ,PPXQRKLVV
RI (IILFDF\ RI)LUVW /LQH 7KHUDES\ LQ 3DWLHQ
7UHDWHG ZLWK &KHPRWKHUDS\ DQG %HYDFL]X

*DUGH 1RDXHUD-5DJQYHQ\HY%#UQHWRPEDUW &DQQR&SPSV +HUUHU &
0HGLFDO 2QFRORJ\ 'HSDUWPHQW DQRYSLWDOHQSDX 6SDQ
0HGLFDO 2QFRORJ\ 'HSDUWPHQW +RVSLWDO GH 6DJXQWR 9DOHQFLD 6SDLQ
\$QDWRPLF 3DWKRORJ\ 'HSDUWPHQW +RVSLWDO 0DULQD 6DOXG 'HQLD 6SDLQ
\$QDWRPLF 3DWKRORJ\ 'HSDUWPHQW +RVSLWDO \$UQDX GH 9LODQRYD 9DOHQFLD 6SDLQ
9DOHQFLD 8QLYHUVLW\ 9DOHQFLD 6SDLQ
&RUUHVSRRGLQJ-DXWWRUDUGH 1RDXHUD 0HGLFDO 2QFRORJ\ 'HSDUWPHQW +RVSLWDO \$UQDX GH 9LO
MDYLUJJDUGH#LFORXG FRP
5HFHYHG GDWH \$X\$KMSWHG GDWH 6HSWHPEHU 3XEOLVKHG GDWH 6HSWHPEHU
&RSULJKW *DUGH 1RDXHUD - HW DO 7KLV LV DQ RSHQ DFFHV DUWLFOH GLVWULEXWHG XQGH WKH
XQUHVWULFWHG XVH GLVWULEXWLRQ DQG UHSURGXFWLRQ LQ DQ\ PHGLXP SURYLGHG WKH RULJLQDO D

\$EVWUDFW
3XUSRVH DZRI WKLW VWXG\ LV WR DQDO\H WKH SURJQRVWLF UROH RI /'+
LPPXQRKLVWRFKHPLVWU\ LQ SDWLHQWV ZLWK DGYDQFHG FRORUHFWDQ FDQFHU W
ZLWKRXX EHYDFL]XPDE
0HWKRGV 5HWURVSHFWLYH PXOWLFHQWUH VWXG\ FDUULHG RXW DW IRXU KRVS
LQYHVWLJDWHG WKH LPPXQRKLVWRFKHPLFDO H[SUHVVLRQ RI /'+ LQ D VHULHV F
DGHQRFDUFLQRPDV WUHDWHG ZLWK R[DOLSODWLQ EDVHG FKHPRWKHUDS\ ZLWK RU
5HVXOWLWWRORJLFDQ VDPSONV IRU WKH /'+ DQDO\LV ZHUH DYDLODEOH IRU F
KDG XQGHWHFWDQOH RU PLOG H[SUHVVLRQ RI /'+ *URXS DQG
H[SUHVVLRQ RI /'+ *URXS 5HVSRRVH UDWL LQ *URXS ZDV FRPSDUHG W
3URJUHVVLRQ IUHH VWYLYDQWV S DQG RYHVDQO PRQWLDQ S26
ZHUH QXPHULFDQ\ EXW QRW VLJQLILFDQW\ KLKBU LQSDWQWUURRURRBS
UHFHYHG EHYDFL]XPDE SUHVHQWHG VWLJQSLFDQWQKDJQPH3J6FDQO\ KLJKHU 2
YV PRQWKV S WKDQ WKRWH WUHDWHG H[FOXVLYHO\ ZLWK FKHPRWKHUDS\
&RQFOXVLRQVUHVXOWV VXJJHVW WKDW WKH DEVHQFH RU ORZ H[SUHVVLRQ RI /'+
SURJQRVWLF SURILOH LQ SDWLHQWV ZLWK DGYDQFHG FRORUHFWDQ FDQFHU WUHD
ZLWK KLJK H[SUHVVLRQ RI /'+ EHQHILW IURP WKH FRPELQDWLRQ RI FKHPRWKHUDS

.HIZRUG\$GYDQ FRORUHFWDQ FDQFHU /'+ H[SUHVVLRQ
\$QJLRJHQHVLV

,QWURGXFWRQ

&RORUHFWDQ FDQFHU &5& LV WKH WKLUG WKH PRVW FRPPRQ PDOLJQDQF\
DQG LV UHVSRRVLEOH IRU DSSUR[LPDWHO\ RI FDQFHU GHDWKV LQ ERWK
VH[HV > @ 2YHU PRUH WKDQ \HUV WKH RQO\ WUHDWPHQW IRU SDWLHQWV ZLV
DGYDQFHG &5& ZDV FKHPRWKHUDS\U\$MLO
DFKHQYD UHVSRRVH UDWL RI H DQGLWRQJOH DJHQW > @
RI[DOLSODWLQ WR FKHPRWKHUDS\ UHJLPHQV EHFDPH D VWHS IRUZDUG IRU
WKHVH SDWLHQWVFDQVWUHDWHG DGHGQFUHDVHG ERWK UHVSRRVH
&RULQDQDORI ([SHULPHQWDO 3DWKRORJ\

SUHGLFW LQ DGYDQFH QMURP SDWLVHQ WVDZLPHQW > @
,W LV VWLOO XQNQRZQ WKH SODFH ZKHUH DQWL 9:*) WKHUDSLHV SURGXFH LWV
PDLQVWKH\ PLJKW KDYHRODVKLHFXPRXU FHOO EXW LW
FRXOG DOVR EDVH LWV DFWLYLW\ RQ WKH HQGRWKHOLDO FHOOV RI WKH EOR
YDVFXODWXUH DQG RU WKH O\PSKDWLF YHVHVOV VXSSRUWLQJ WKH WXPXU ZKH
LW KDV EHHQ GHWHFWHG D RYHUH[SUHVVLQR RI 9(*)5 .5 DQG
9(*)5 UHFHSWRUV 9(*)5 LV LQYROYHG LQ WKH LQLWLDWLRQ RI
PROHFXODU SDWKZD\W WKDW LQGXFH SUROLIHUWLRQ DQG VXUYLYDO RI
HQGRWKHOLDO FHOOV > @ 2YHUH[SUHVVLQR RI WKH DFWLYDWHG IRUP RI
9(*)5 RU S.5 PHDVXUHG E\ LPPXQRKLVWRFKHPLVWU\ DV ZHOO DV RI
ODFWDWH GHK\GURJHQDVH /'+ SURWHLQ LQYROYHG LQ WKH UHJXODWLRQ RI

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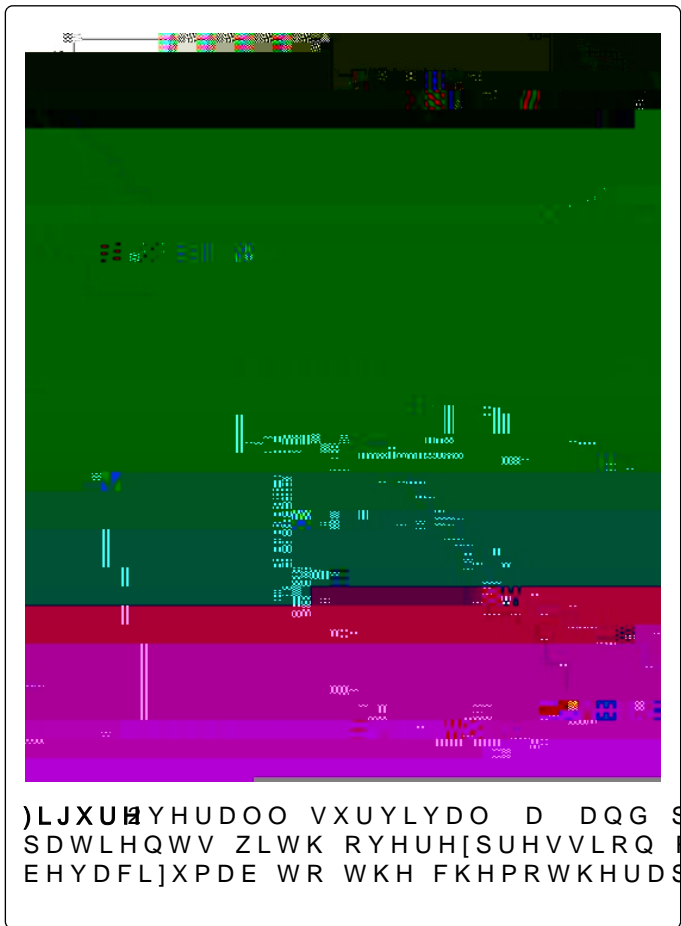
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,Q RXU GDWDEDVH ZH IRXQG SDWLHQWV GLDJQRVHG ZLWK DGYDQFHG
&5& WUHDWHG ZLWK XR[UDPS\SLFV\BQ\BQ\LRQ
FKHPRWKHUDS\ ;(/2; RU)2/)2; ZLWK RU ZLWKRXW EHYDFLJXPDE
(LJKW\ VHYHQ\W\W\PHW\DGDO IRU KLVWRORJLFDQ DQDO\VLV RI
'+

/'+ H[SUHVVLQR FRPSOHWH UHVSQRVH SDUWLDO UHVSQRVHV VWDEOH
 GLVHVVH DQG SUBUHVHVLQF WYGL 55 DMHWZHHQ WKH
 WZR JURXS ZHUHVQRQL)SDQWHVWZLFDOR
 VLJQL)SDQWHVWZLFDOR FKHPRWKHUDS\ DQG
 EHYDFL]XPDE LQ *URXS DFFRUGLQJ WR WKH ORFDWLRQ RI /'+
 H[SUHVVLQR WYGLSDQWHVWZLFDOR YV YV
 S

2YHUDOO VXUYLYDO DQG SURJUHVVLRQ IUHH VXUYLYDO

H PHGLDQ VXUYLYDO LQ *URXS ZDV PRQWKV FRPSDUHG WR
 PRQWKV LQ *URXSBUHVS QGLWKUHQ F3)6
 PRQWKV PRQWKV LQ *URXS DQG HUHSHFWLYHO\ S
 PHGLDQ 26 LQ WKRVH SDWLHQWV LQ *URXS ZKR UHFHLYHG WUHDWPHQW ZLWK
 FKHPRWKHUDS\ LQ FRPELQDWLRQ ZLWK EHYDFL]XPDE ZDV PRQWKV
 FRPSDUHG WR PRQWKV LQ WKH SDWLHQWV WUHDWHG ZLWK FKHPRWKHUDS\
 DORQH S VL3)GLZDQWU LQ *URXS IRU SDWLHQWV
 WUHDWHG ZLWK EHYDFL]XPDE)LJXUH



)LJXUH YHUDOO VXUYLYDO D DQG SURJUHVVLRQ IUHH VXUYLYDO E LQ
 SDWLHQWV ZLWK RYHUH[SUHVVLQR RI /'+ DFFRUGLQJ WR WKH DGGLWLRQ RI
 EHYDFL]XPDE WR WKH FKHPRWKHUDS\ WUHDWPHQW

'LVFXVVLRQ

LVUHWURVSHFWLYH VWXG\ ZDV GHVLJQHG WR DQDO\WH WKH SURJQRVWLF UROH
 RI WKH RYHUH[SUHVVLQR RI ODFWDWH GHK\GURJHQDVH /'+ LQ SDWLHQWV
 GLDJQRVHG ZLWK DGYDQFHG FRORUHFWD DGHQRFDUFLQRPD WUHDWHG ZLWK
 FKHPRWKHUDS\ ZLWK~RRDQSSWDFWGLQ QDQ

WKLW VWXG\ FDUULHG RXW EDVHG LRG UHPOO VDP SOH RI SDWLHQWV ZLWK
VWDJH RI WKH GLVHDVH IURP SUHYHQVGRVHULHV PDNHV LW YHU\
DQ\ FRPSDULVRQ

H DQDO\VLV RI SDWLHQWV ZLWK /'+ RYHUH[SUHVVLQR DFFRUGLQJ WR
WUHDWPHQW ZLWK FRQWVWDOV SDWLHQWV WUHDWHG ZLWK
EHYDFL]XPDE SUHVHQWHG D ORQJHU 3)6 DQG VKRZHG D IDYRXUDEOH WUHQG LQ
WHUPV RI 26 FRPSDUHG WR WKRVH WUHDWHG H[FOXVLYHO\ ZLWK FKHPRWKHUHS\
H OLPLWHG QXPEHU RI SDWLHQWV H[FOXVLYHO\ ORZ /'+ H[SUHVVLQR
RXU VWXG\ SUHYHQWHG WUHDW DQDO\VLH FRXOG
DGG WR FKHPRWKHUHS\ LQ SDWLHQWV ZLWK ORZ H[SUHVVLQR RI WKLW
DQJLRJHQHVLV PDUNHU DQG DOVR SUHYHQWHG XV WR DVVHVW WKH K\SRWKHWLF
SURJQRVWLF UROH RI WKDW PDUNHU LQ WKLW FRQWH[W 3UHYLRXV UHSRUWV IRX
VLPLODU UHVXOWV UHJDUGLQJ WR WKH EHWWHU RXWFRPH RI SDWLHQWV ZLW
RYHUH[SUHVVLQR RI SUR DQJLRJHQLF SURWHLQV ZKHQ WUHDWHG ZLWK
%HYDFL]XPDE %RWK SDWLHQWV ZLWK KLJK OHYHOV RI S.'5 PHDVXUHG E\
LPPXQRKLVWRFKHPLVWU\ DQG SDWLHQWV ZLWK KLJK VHUXP OHYHO RI /'+
SUHVHQWHG D

&LWDWLEBQGH 1RJXHUD - *LO 5DJD 0 (YJHQ\HYD (%HUQHW / /ORPEDUW &XVDF \$ HW
,PPXQRKLVWRFKHPLFDO ([SUHVVLQR DV 3UHGLFWRU RI (ILFDL\ RI)LUVW /LQH 7KHU
ZLWK &KHPRWKHUDS\ DQG %HYDFL]XPDE - &OLQ ([S 3DWKRO

VPDOO FHOO OXQJ FDQFHU WLVVXH LV OLEDNHWRW WKPWNG ZLSRKLKHPQWLRHHSF SOX
IDFWRU SURGXFWLRQ DQG SRRU SURJQRVLV %U - &DQFHU
6FDUWR]LDPSLHUL 5 ODFFDURQL ('HO 3UHNDKD\NORS\$KLEHWDD PDWXUH IRUP RI .
3UH WUHDWPHQW ODFWDWH GHYKQBRJHQDYHUEHMEWRDV SUHGLFWRUHVRWKH 3/& JD
R]UUVW DLDL]XPDE EDVHG WKHUDS\ LQ PHQW\FDWLFLWRORL]FURDQDQDQHQH 7
SDWLHQWV %U - &DQFHU 4XLQQ 73 3HWHUV .* 'H 9ULHV &)HUUDUD
*DUGH 1RJXHUD - *LO 5DJD 0 (YJHQ\HYD (ODUFDNLSQDORPEDUW &XVDFSWRU IRU YDVFX
\$ HW DO +LJK S.'5 LPPXQRKLVWRFKHPLFDFDQWYSHOHVHLSRQVWHQQLQ YDVFXODU HQ
XQIDYRXUDEOH SURJQRVWLF ELRPDUNHU LQ SDWLHQWV ZLWK DGYDQFHG FRORUHFWD